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DEVELOPMENT OF METHODOLOGY TO PERMIT PROJECTION OF AIR POLLUTION EMISSIONS FOR GEOGRAPHIC AREAS

RESEARCH TRIANGLE INSTITUTE

PREPARED FOR
ENVIRONMENTAL PROTECTION AGENCY

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THE DEVELOPMENT OF METHODOLOGY TO PERMIT PROJECTION OF AIR POLLUTION EMISSIONS FOR GEOGRAPHIC AREAS

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16. Abstracts The purpose of this study was to provide a conceptual design of a model to project regional air pollution emissions. Existing national economic forecasting models were examined to determine the extent to which such a model could be disaggregated to provide regional forecasts. Only the OBERS model used by the U.S. Department of Commerce was found to be appropriate, and its use was primarily to provide control totals by State. It was determined that new model components would be required to project regional values for area and mobile sources and for each industrial source to be forecast. Mobile source emissions can be estimated on the basis of population, the stock of motor vehicles and its age composition, and vehicle use patterns. Area source emissions can be estimated on the basis of population, fuel use patterns, and projected employment. Industrial point source emissions will require the application of industrial growth and location theories to each industry individually. The required data is available or can be developed for each model component. The analysis sets forth the functional relationships of the proposed model, its structural and data requirements, and evaluates its limitations.

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The project was under the direct supervision of Alvin Cruze and David LeSourd. Responsibility for analysis and writing of the sections of this report was as follows: Alvin Cruze, for the evaluation of existing models; Tayler Bingham, for model evaluation and analysis of mobile sources; Paul Mulligan, for the treatment of industrial point sources; David LeSourd, for the treatment of area sources; and Robert Thornton and Philip Cooley, for defining the model structure and computer requirements.

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SECTION 1

INTRODUCTION AND SUMMARY

The purpose of this project, as stated in the contract, has been to "perform a study of the feasibility of using modelling techniques in order to project air pollution emissions for a given geographic area." To a great extent, feasibility has been determined by defining the elements required by such a model and the availability of the requisite data and projection methodologies. The research has produced a conceptual design of a feasible regional projection model. This report describes the evaluations that have been made and the model design that has been evolved.

1.1 Scope of the Research

At the outset of this study it was apparent that what would be most immediately useful to the Environmental Protection Agency (EPA) was a computerized model that would project probable air pollution emissions by source for areas no larger than air quality control regions (AQCR's) and for dates well into the future. This would require the design of a means of relating forecasts of aggregate economic activity to population changes, the growth of output in specific industries, changing technology, and other variables, in specific geographic locations. Projections of these variables could then be used to estimate the pollutant emissions from identified mobile, area, and point sources. These emissions estimates would permit EPA to identify those AQCR's in which emissions might be expected to rise above acceptable levels and, therefore, to initiate policy changes in cooperation with State authorities before critical levels of pollution occur.

The scope of this project was limited to consideration of the feasibility of constructing a model that would (a) provide projections for two points in time, i.e., 10 years and 20 years from date; (b) project emissions of particulates, sulfur oxides, nitrogen oxides, carbon monoxide, and hydrocarbons; (c) be interconnected to projections of the aggregate of the national economy; and (d) provide estimates disaggregated to the county or air quality control region level.

The analysis examined the availability of national econometric models with regional components that could be disaggregated to the required level of geographic and industrial detail. Studies were made of the required methodology and data availability for projections of mobile, area, and point sources of significant emissions of the candidate pollutants. The structure of the computer model that would be required was also examined as well as the capabilities and limitations of the total model.

1.2 Summary

A number of existing national econometric models were evaluated to determine their usefulness as a basis for constructing the desired model. Of these, only that employed by the Bureau of Economic Analysis (BEA), U. S. Department of Commerce appeared to offer substantial support for this effort. That model provides estimates of population, personal income, employment and earnings by industrial sector for 173 areas of the U.S. These projections can provide essential control totals against which to check AQCR projections. Some of the BEA data series can also be disaggregated to provide AQCR data.

In dealing with the problems associated with projecting mobile source emissions most of the effort in this study has been focused on passenger cars, gasoline powered trucks, and aircraft, although consideration is also given to other trucks and buses. A method is proposed for providing projections of automobile emissions based on automobile registrations and estimated annual vehicle miles. It appears that the essential data for this method are available and that it can provide more accurate estimates and be more useful for sensitivity analysis and policy evaluation than any alternative system. The model design discussed, however, will not provide full compensation for the interregion variations caused by commuting patterns.

A similar projection model is proposed for trucks and its specifications and limitations discussed. Aircraft emissions in the vicinity of most airports can be projected directly from presently published Government data.

Projections of area source emissions from fuel combustion for heat and power require a large volume of detailed calculations but are not conceptually difficult. They can be based on fuel consumption patterns available by State in regularly published data. These can be allocated to residential, commercial, institutional, and industrial heating use and projected on the basis of population and employment patterns.

Fossil fueled electric generating plants comprise a special case of fuel consumption sources. For modelling purposes they have some of the characteristics of both the area sources and the point sources. However, a very large body of detailed data is available on electric utilities and, except for the location problem, projections of these emissions are relatively easy to construct.

Emissions arising from a number of point sources that are industrial plants are considered in this analysis. Projection of emissions from industrial production processes must be based largely on projections of each industry's production and capacity and regional allocations provided by the application of economic location theory. No general method of disaggregation from national or area forecasts seems likely to provide the desired level of accuracy at the specified 10 and 20 year time horizons. Projections of these emissions will almost certainly prove to be the most difficult part of the overall model construction effort. This analysis provides a detailed evaluation of the significance of various point sources and the relative complexity of the problems related to projecting their emissions. It is clearly established that construction of this segment of the model is feasible.

This report also provided a detailed discussion of the structure and capability of the computer programs that may be used in the actual construction and implementation of the desired projections model.

1.3 Model Structure

1.3.1 Mobile Sources

1.3.1.1 Passenger Cars. The model segment for estimating emissions from passenger cars will require the following inputs:

1. Equilibrium stock of automobiles per capita, as a function of income, population density, and other.
2. Retirement rate, as a function of vehicle age.
3. Average annual mileage per vehicle by model year, divided into two average speed classes (rural and urban).
4. Emissions factors by model year and average speed class.
5. Regional distribution of the base year national stock of automobiles.

The equilibrium stock of automobiles for any projected year includes new purchases and the carry over of stock from the previous year. Knowing the retirement rate by model year, it is possible to calculate the age distribution of the projected stock. This, multiplied by the average annual mileage per vehicle by model year, gives total mileage, which is then divided into speed categories, and multiplied by emission factors, to provide the national emission estimate. When the equilibrium stock is disaggregated to regions, the same procedure will yield projected regional emissions.

1.3.1.2 Trucks. Emissions generated by the operation of trucks may be calculated in the same way as outlined for passenger cars. It is necessary, however, to classify trucks as light and medium duty gasoline powered, heavy duty gasoline powered, and diesel powered, and project the stocks, vehicle miles, and emissions for each category.

1.3.1.3 Aircraft. National and regional ten year projections of aircraft activity at airports are provided by FAA. Data is also available on aircraft types relative to types of use and airport size and future aircraft use is also forecast by FAA. These projections may be extended to the years required by this model and the appropriate emission factors applied to derive emission projections by region.

1.3.2 Area Sources

Required inputs for the calculation of emissions from area sources are:

1. Base year consumption of fuels for heating, by state.
2. Population, by AQCR.
3. Average family size.
4. Average number of persons per dwelling.
5. Commercial-institutional and industrial employment.
6. Emission rates by fuel and heating class.

1.3.2.1 Residential Heating. Data are available on consumption of fuels for heating by state. Heating demand in 1970 for the average residence in each state may be calculated by dividing total fuel consumption for residential heating, in Btu's, by the number of dwelling units. Assuming that this relationship remains constant, future demand can be projected on the basis of population, family size, and dwelling unit size. Total residential heating demand can be apportioned to fuel types on the basis of the market share trends by state, and may be disaggregated to AQCR by county population. The product of this analysis will then be fuel consumption by AQCR, from which projected emissions may be estimated.

1.3.2.2 Commercial-institutional and Industrial Heating. Commercial-institutional and industrial consumption of fuels for heating may be calculated in similar manner. Baseline data-on fuel consumption for these categories can be developed from regular Government reports. The ratio of commercial-institutional heating demand in Btu's to commercial employment by state, can be used to estimate future consumption as commercial employment changes. In the same way, industrial heating demand may be projected on the basis of industrial employment. The two employment series may be used to disaggregate state fuel consumption to AQCR's. Emission estimates may be made by applying appropriate emission factors to the fuel consumption patterns.

1.3.3 Point Sources

Inputs required for the analysis of emissions from industrial point sources are:

1. Present location of plants, by industry.
2. Production rates, by plant and process.
3. Process use, by plants in each industry.
4. Level of controls in place, by plant.
5. Emission rates, by production process.

Each industrial classification will have to be projected separately. National output, by 2-digit SIC, can be projected based on available Government and private forecasts. Data are available from other research to permit disaggregation of current industry output figures to the required detail of product type and production process for most industry categories. Estimates of future production may be based on trend analysis modified exogenously to allow for expected changes in technology. Geographic disaggregation will require, for some industries, careful application of industry location theory to estimate growth of those industries in new locations. Where limited growth is predicted or where location is determined by resource availability, and therefore unlikely to change, the model will assume that any growth occurs where plants are already in existence. Emission factors related to production rates may then be applied to production estimates to provide estimated future emissions by AQCR.

SECTION 2

EVALUATION OF MODELS TO PROJECT REGIONAL ECONOMIC ACTIVITY

2.1 Introduction

In its efforts to improve the quality of the environment, the Environmental Protection Agency (EPA) faces a continually changing situation as economic and social forces create growth, stagnation or possibly decline in various areas of the Nation. These changes may cause changes in industrial production, housing density, motor vehicle operation, and other activities giving rise to air pollution emissions. Through economic growth and uncontrolled emissions of pollutants, some areas of the Nation already have experienced problems associated with critical levels of air pollution. These areas for the most part are known and for them the primary task is to reduce or prevent further increases in pollution. Other areas, that are marginal in terms of pollution problems today, may reach critical levels of air pollution in the future through economic growth and changes in production techniques.

Early identification of areas with potential for pollution is required so that steps can be taken to forestall major pollution problems. This identification requires a model of regional growth, expressing the interrelationships among economic, demographic and air emission factors, within a framework of projected national growth. This study is the first phase of a multi-phase undertaking and is designed to conceptualize the overall model and to specify the work required in later stages.

In order to project air emissions from the variety of sources, a procedure to forecast the distribution of population and economic activity among the various regions of the Nation is required.[1] Several models and techniques for projecting population and economic activity for isolated regions--river basins, states, groups of counties--have been developed and are currently operational. However, since EPA is interested in projections for regions distributed over the entire Nation, these models are not appropriate for this project.

---

[1] The terms, project and forecast, are used interchangeably in this report. Each has the same meaning--indicating what is likely to happen in the future under stated assumptions and the continuation of recent trends in the Nation's social and economic system. It should be noted that the results of this process do not indicate what will happen in the future, only what is likely to happen.

Several models developed on a nationwide basis, which include projections of selected variables on a sub-national or regional basis, are appropriate for this project, and have been reviewed and evaluated. One model is recommended for later stages of the overall effort to develop procedures to project air emissions.

It should be noted that none of the currently existing models is completely acceptable for EPA purposes. In particular, none provides projections at the appropriate level of detail, either at the industrial level or, more importantly for projecting air emissions, at the industrial process level of detail. This was anticipated and the survey was planned to:

1. Ascertain which of the existing models was most appropriate to provide a) the required regional projections developed within the framework of national projections and b) the necessary control totals for more detailed projections, and
2. Recommend additional model development efforts required to implement the entire system for projecting regional air emissions.

2.2 Evaluation

In order to establish a rational basis for reviewing, comparing, and evaluating the various existing models for projecting population and economic activity, a set of evaluation criteria was established. These include: time frame for which projections are currently available; geographic and industrial detail of the model's projections; basic assumptions underlying the projections; units in which economic activity is projected, including consistency among the various measures projected; data requirements; ease of updating the model and revising the associated projections; and acceptability for sensitivity analyses in which the changes in projections of air emissions resulting from changes in model inputs are evaluated.

Five models were reviewed during this effort:

1. The projections developed for the United States Water Resources Council by the Office of Business Economics of the U. S. Department

of Commerce and the Economic Research Service of the U. S. Department of Agriculture (the OBERS projections),[2]

2. A multi-regional, multi-industry forecasting model developed by Curtis Harris at the University of Maryland (the Harris model),

3. The multi-regional input-output model sponsored by the Economic Development Administration of the U. S. Department of Commerce and developed at Harvard University (the MRIO model),

4. The economic and demographic projections developed by the National Planning Association (the NPA projections), and

5. Projections developed at the Institute for Defense Analyses and sponsored by the Office of Civil Defense of the Defense Department (the OCD projections).

In addition, 1980 projections of labor force, aggregate and industry demand, output, and the industrial and occupational structure of employment, developed by the Bureau of Labor Statistics (BLS) of the U. S. Department of Labor are briefly discussed. These projections result from the cooperative efforts of several government agencies working under the auspices of the Interagency Economic Growth Project and are termed to BLS projections in this memorandum. Although the BLS projections do not contain any regional detail, they do provide certain types of industrial detail at the national level which might prove useful in the EPA overall model development effort.

Based on the above criteria, the OBERS projections and projection methodology are recommended for use by EPA to provide the overall framework for projecting air emissions. The OBERS projections provide an excellent set of consistent regional projections of population, personal income, employment and earnings at an adequate degree of industrial detail. The projections are provided for a time frame that falls within the EPA period of interest (10-20 years into the future). Furthermore, the data base associated with the OBERS methodology is structured in such a manner that the projections can be provided for a variety of geographical areas.

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[2] The identifiers in parentheses indicate the means by which the various models are referenced throughout this report. Complete references to published documentation are provided with discussions of the models in Appendix A.

The OBERS projections have been developed for the United States Water Resources Council and will serve as the official projections of population and economic activity which must be followed by all agencies planning water resource projects. Thus, the use of these projections as the overall framework for air emission projections will insure consistency in the longe-range planning efforts of both air and water programs.

In addition, the Bureau of Economic Analysis (BEA) of the U. S. Department of Commerce (formerly the Office of Business Economics) is committed to maintaining the required data base, improving the projection techniques, and updating the projections on a regular basis. The fact that these tasks will be accomplished by another organization will permit EPA to devote its resources to developing and refining the portions of the overall methodology for projection air emissions.

Review of the OBERS methodology, indicates that the associated projections will be most useful for projecting air emissions from mobile and area sources. Emissions from these sources are functions of a number of variables, two of the most important of which are population and income. As noted above, projections of these key variables are contained within the OBERS framework. With respect to projecting emissions from point sources, the OBERS projections are less complete. The industry sector and industrial process detail necessary for projecting industry are not available within the OBERS framework. Therefore, although the OBERS projections can serve as overall control totals for the necessary projections of detailed industrial activity, efforts will be required to develop procedures by which these detailed projections can be provided within the OBERS framework.

Details of the review and evaluation of each of the six models are presented in Appendix A. For each model the discussion is organized around major headings of general characteristics, detailed characteristics, operating procedures and overall evaluation for EPA use. To provide appropriate information for the recommended methodology, the OBERS model is discussed in greater detail than the other models.

SECTION 3

PROJECTING EMISSIONS FROM MOBILE SOURCES

3.1 Introduction

Mobile sources, especially gasoline powered motor vehicles, are one of the major sources of air pollution. Projection of emissions from mobile sources on a regional level is an especially challenging task, not only due to their mobile character, but also because emissions vary with vehicle utilization, vehicle speed, and the age distribution of the vehicle population, all of which are difficult to forecast. Methodologies for projecting gasoline and diesel powered motor vehicle and aircraft activity and their associated emissions are discussed below. General equations are presented and variables identified. During the actual estimation of the relationships the form of the equations and the variables included may change somewhat. Most of the emphasis is on passenger cars because of their dominant role in mobile source emissions.

3.2 Gasoline Powered Motor Vehicles

3.2.1 General

Gasoline powered motor vehicles consist of passenger cars, trucks, buses and various other vehicles. Emissions for this category of mobile combustion sources vary with vehicle miles, model year and speed of the vehicle.[1]

Because passenger cars and trucks account for almost all motor vehicle emissions it appears most cost-effective to project emissions only from these sources. Buses, however, can probably be fairly easily and reasonably included with trucks if desired.

EPA has a computer program (PAVE-I)[2] for calculating motor vehicle emissions, given certain inputs. The program essentially solves the following equation:

$$\phi = \sum_{i=1}^{n} N_i q_i v_i \qquad (1)$$

ϕ = total annual emissions,

N_i = number of motor vehicles by model year,

q_i = emissions factor for each model year,

v_i = average annual mileage per vehicle by model year,

n = number of model years.

3.2.2 Passenger Cars

In 1969 of 105 million registered motor vehicles, 83 percent (87 million) were passenger cars.[3] Because they are the dominant source of emissions from mobile combustion sources, they have received the most attention in this study.

The objective of an emissions projection methodology for passenger cars is to provide a procedure for projecting, first on a national basis and subsequently on a regional basis, the number of passenger cars by model year, the vehicle miles traveled by each model year, and the distribution of those vehicles miles between urban and rural travel. Figure 1 illustrates the major elements in the suggested model and their relationships.

3.2.2.1 Passenger Car Projection Model. Most economists working on the problem of automobile demand have been concerned with projecting the short run demand for automobiles. They have examined such variables as: consumer income, automobile prices, credit conditions, used car allowances, operating costs and dealers' used car stocks in an effort to explain the shifts in demand for new automobiles. Some insight into the difficulty of such projections of new automobiles can be gained by observing the large changes in the sales of new automobiles from year to year, shown in Figure 2.

Since we are interested in long term trends in automobile ownership rather than year-to-year changes in the demand for new automobiles and because it is quite difficult to project many of the variables identified above, a more straight forward approach should be sufficient. The approach set forth below would use the data provided in the BEA projections to make the automobile emissions projections.

Since automobiles yield a transportation service over a period of several years, and since we are interested in emissions projections for the entire stock of automobiles, the most useful approach to developing trend projections is to begin by projecting the demand for a stock of automobiles and then to project the age distribution of that stock. As shown in Figures 3 and 4 on both an absolute and per capita basis the stock of automobiles has shown a fairly regular annual increase since 1950.

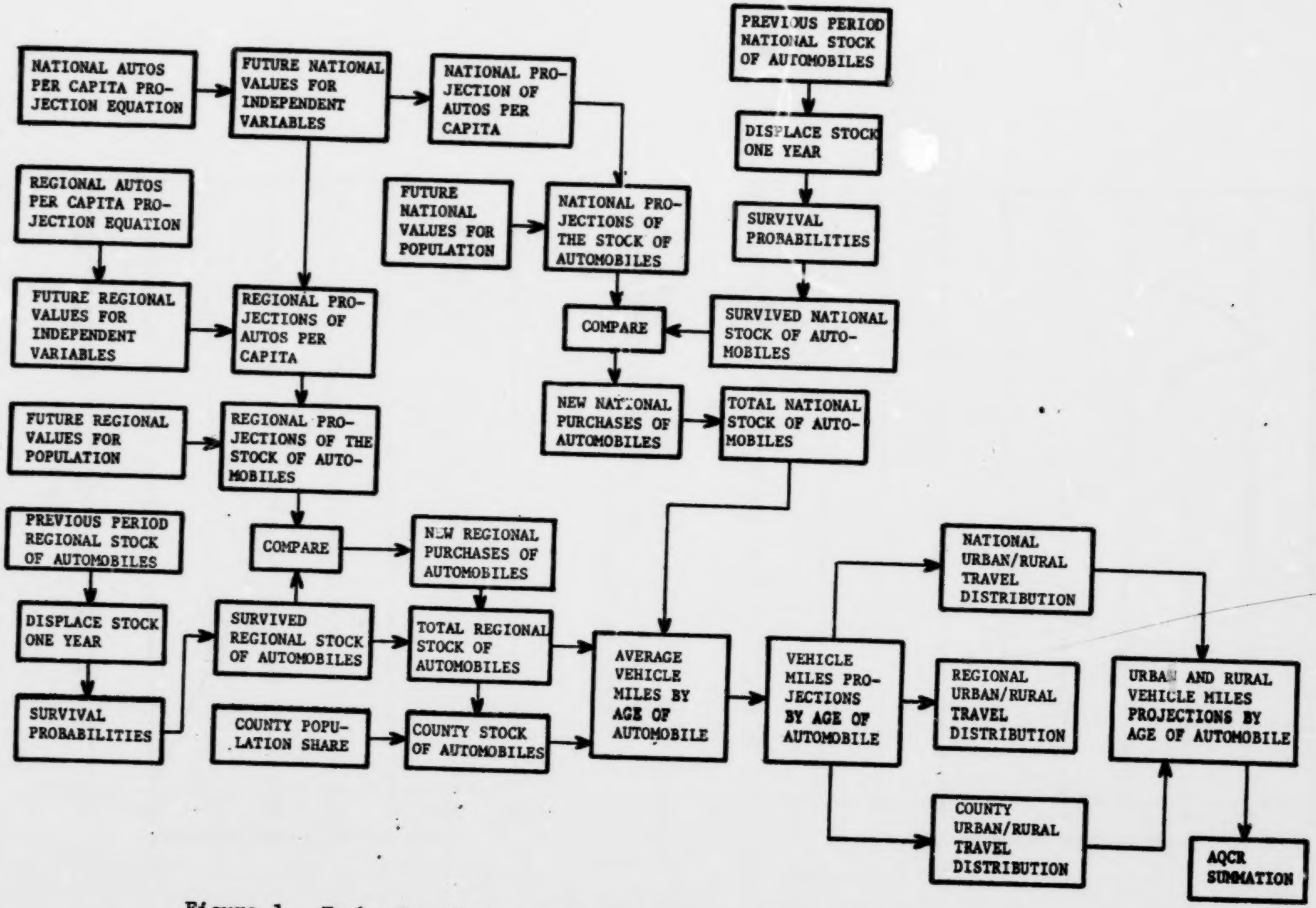
NATIONAL AUTOS PER CAPITA PROJECTION EQUATION
FUTURE NATIONAL VALUES FOR INDEPENDENT VARIABLES
NATIONAL PROJECTION OF AUTOS PER CAPITA
PREVIOUS PERIOD NATIONAL STOCK OF AUTOMOBILES
DISPLACE STOCK ONE YEAR
REGIONAL AUTOS PER CAPITA PROJECTION EQUATION
FUTURE NATIONAL VALUES FOR POPULATION
NATIONAL PROJECTIONS OF THE STOCK OF AUTOMOBILES
SURVIVAL PROBABILITIES
FUTURE REGIONAL VALUES FOR INDEPENDENT VARIABLES
REGIONAL PROJECTIONS OF AUTOS PER CAPITA
COMPARE
SURVIVED NATIONAL STOCK OF AUTOMOBILES
FUTURE REGIONAL VALUES FOR POPULATION
REGIONAL PROJECTIONS OF THE STOCK OF AUTOMOBILES
NEW NATIONAL PURCHASES OF AUTOMOBILES
TOTAL NATIONAL STOCK OF AUTOMOBILES
PREVIOUS PERIOD REGIONAL STOCK OF AUTOMOBILES
COMPARE
NEW REGIONAL PURCHASES OF AUTOMOBILES
NATIONAL URBAN/RURAL TRAVEL DISTRIBUTION
DISPLACE STOCK ONE YEAR
SURVIVED REGIONAL STOCK OF AUTOMOBILES
TOTAL REGIONAL STOCK OF AUTOMOBILES
AVERAGE VEHICLE MILES BY AGE OF AUTOMOBILE
VEHICLE MILES PROJECTIONS BY AGE OF AUTOMOBILE
REGIONAL URBAN/RURAL TRAVEL DISTRIBUTION
URBAN AND RURAL VEHICLE MILES PROJECTIONS BY AGE OF AUTOMOBILE
SURVIVAL PROBABILITIES
COUNTY POPULATION SHARE
COUNTY STOCK OF AUTOMOBILES
COUNTY URBAN/RURAL TRAVEL DISTRIBUTION
AQCR SUMMATION

Figure 1. Tasks for Projection Regional Motor Vehicle Activity.

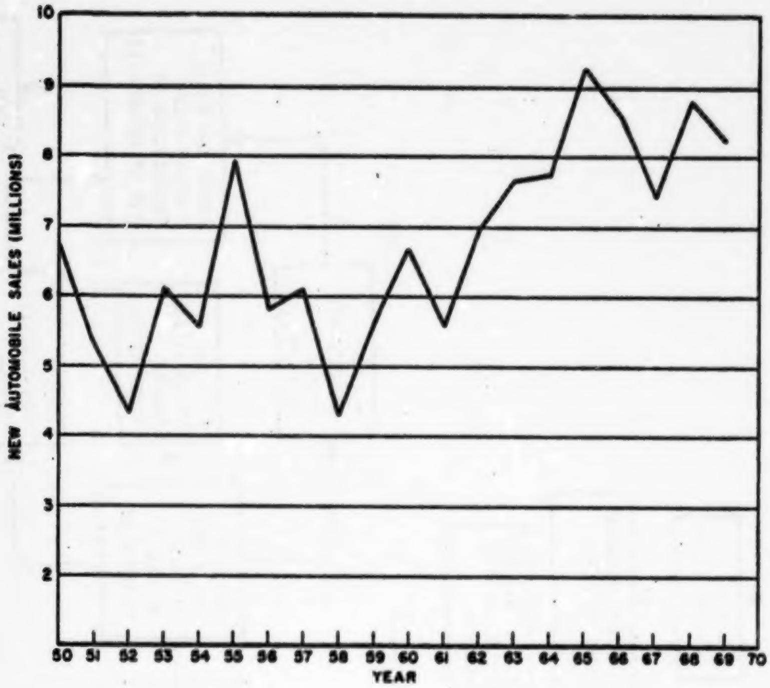

Figure 2. New Automobile Sales (Source: Automobile Manufacturers Association, 1970-Automobile Facts and Figures).

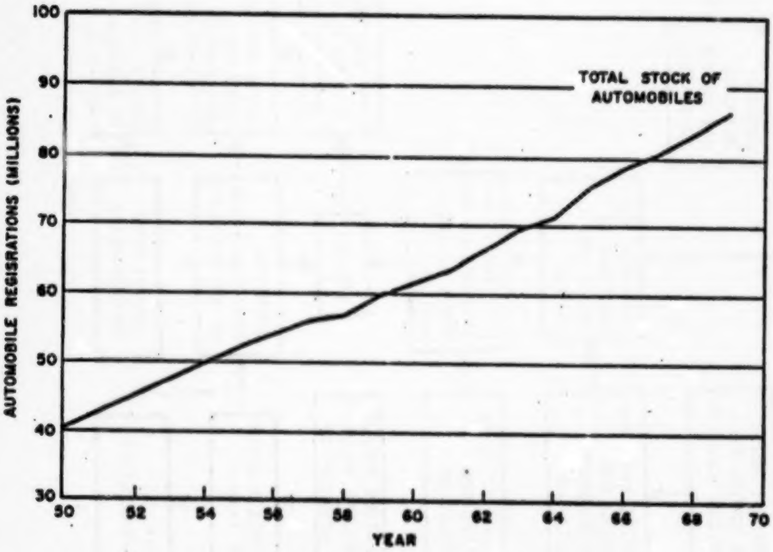

Figure 3. Stock of Automobiles (Source: Automobile Manufacturers Association, 1970 Automobile Facts and Figures).

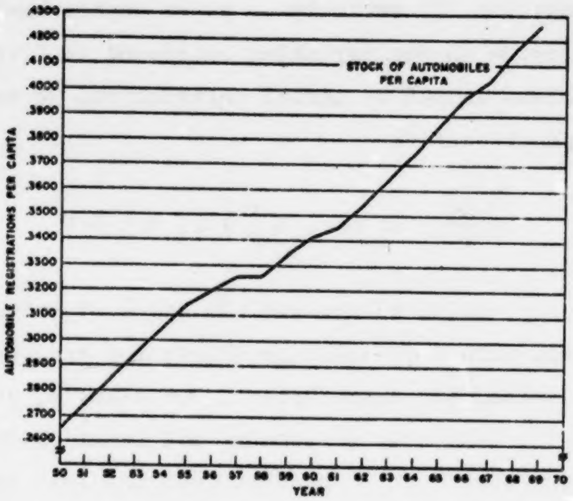

Figure 4. Stock of Automobiles Per Capita (Source: Automobile Manufacturers Association, 1970 Automobile Facts and Figures).

Stock adjustment models have been applied to demand analyses for consumer durables by several researchers, the most complete being a set of 82 consumer demand models by Houthakker and Taylor.[4] The behavioral hypothesis underlying these models of consumer demand for durable expenditures is that current purchases depend in part on the pre-existing stock of the item in question. Current purchases are treated as an attempt by consumers to adjust this stock toward some equilibrium level. The rate of adjustment is usually a function of anticipated economic conditions.

Consumers can be viewed as expected to possess an equilibrium automobile stock based on their income, location, and various other factors as represented by the following model:

$$SA = f_1(Y,L,U) \tag{2}$$

where:

SA = the expected equilibrium automobile stock
Y = the expected income
L = the expected population density
U = the error term which is the combined effect of the omitted forces.

Expressing equation (2) entirely on a per capita basis and assuming linear relationships, with the variables expressed in first differences to reduce the problems caused by serial correlation, we have the following model specification:

$$\Delta \frac{SA}{P} = a_1 + a_2 \Delta \frac{Y}{P} + a_3 \Delta L + U \qquad (3)$$

It is especially useful to present the stock of automobiles on a per capita basis because such a formulation allows for the possibility of a saturation in the demand for automobiles. For example, as shown in Figure 5, on a family basis the percent of all families owning automobiles has been stable at 80 percent over the last seven years. The source of the increase in the per capita stock of automobiles has apparently been the increase in family multi-car ownership.

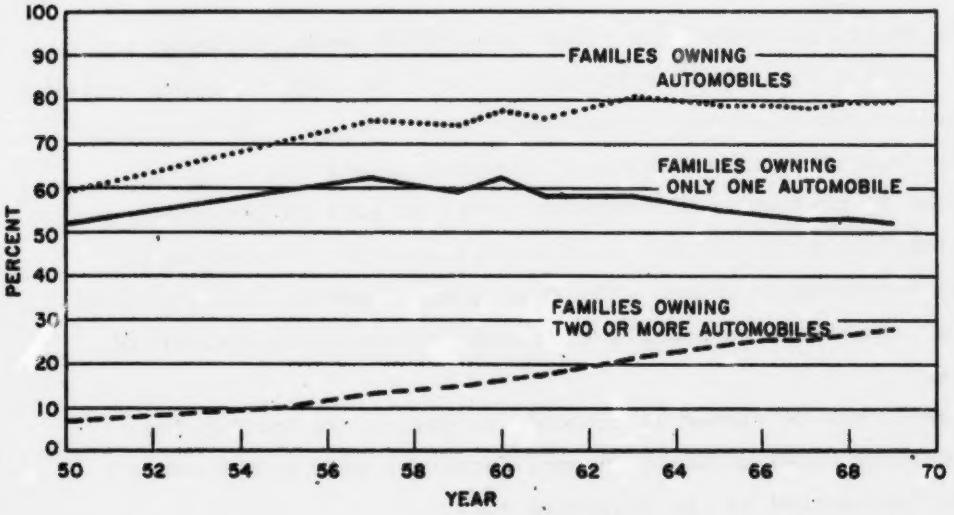

Figure 5. Family Automobile Ownership. (Source: The University of Michigan, Survey Research Center, Survey of Consumer Finances)

Because of differences in automobile emissions from model year to model year, the age distribution of the stock of automobiles is particularly important. This places special emphasis on (RA), the number of automobiles retired. It is, therefore, necessary to project (RA) for each model year.

A review of the literature did not yield any studies of automobile retirement. One of the major reasons for retirement is probably the cost of repair. As the ratio of the cost of replacement to the cost of repair falls the rate of retirement would be expected to increase. For newer cars, severe accidents are the primary reason for their retirement. For older models, less severe accidents or repair costs due to mechanical failures are important factors.

While a thorough study of the trends in accidents, their severity, cost of repair, and replacement costs would be possible, it would appear that a more cost-effective approach would be to assume (RA) to be a stable function of vehicle age. Therefore:

$$RA_{it} = k_i SA_{i(t-1)} \quad \begin{array}{l} (i = 1,2,3 \ldots n \text{ model years}) \\ (t = \text{time by year}) \end{array} \tag{4}$$

Figure 6 shows survival probability functions on both a cumulative and an annual incremental retirement basis. While the function is usually expressed on a cumulative basis, the annual incremental basis is more useful for sensitivity analysis. For example, as shown in Figure 6, about 84 percent of the seven year old vehicles are expected to be registered in the eighth year. However, it may be useful to examine the effect on emissions if the percent rose to 95 percent due to the higher new car prices expected with emissions control systems. The annual change function provides the best method for allowing for the incorporation of such possibilities.

Using the survival probability function it is possible to compute the total number of cars retired in each year:

$$RA_t = \sum_{i=1}^{n} RA_{it} \tag{5}$$

The number of new automobiles (XA) purchased at time (t) can be obtained by subtraction:

$$XA_t = SA_t - SA_{t-1} + RA_t \tag{6}$$

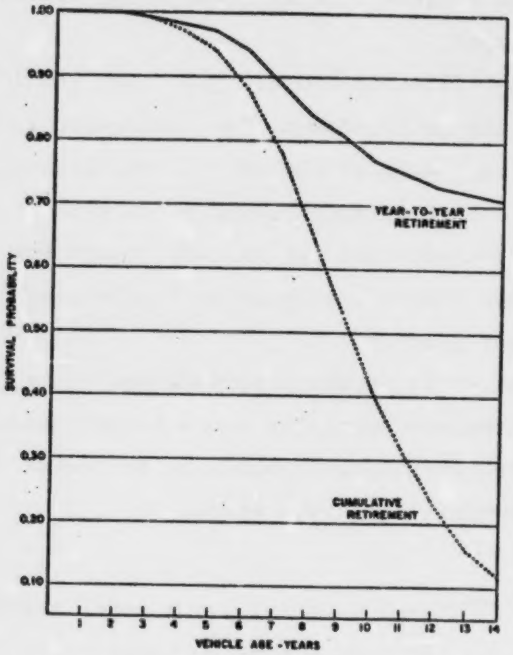

Figure 6. Automobile Survival Probabilities. (Source: Research Triangle Institute)

3.2.2.2 Vehicle Miles Projections. A passenger car projection model of the type described above provides projections of the stock of automobiles by vehicle age. The next step is to convert these stock projections to vehicle miles. The PAVE-I model has a procedure for calculating vehicle miles. It uses a function which relates the average annual mileage (V_1) per vehicle by model year to vehicle age. Table 1 shows this relationship on a national average basis.

There is probably a significant variation in this functional relationship from region to region. For example, motor vehicles operated in the Great Plains States where there are straight roads, with high speed limits and low population densities probably have a higher average annual mileage than do motor vehicles operated in urban areas.

Table 1. ANNUAL MILEAGE AS A FUNCTION OF VEHICLE AGE

Car Age (years)	Average Annual Milage Per Car
1	17,500
2	16,100
3	13,200
4	11,400
5	11,700
6	10,000
7	10,300
8	8,600
9	10,900
10	8,000
11 or more	6,500

Source: U.S. Department of Transportation, Nationwide Personal Transportation Study, Annual Miles of Automobile Travel, Report No. 2, April 1972, p 9.

The regional differences may vary inversely with population densities and if so, functional relationships may be able to be developed to adjust the national relationship for each region based on its projected population density.

3.2.2.3 Vehicle Speed Distributions. Motor vehicle emissions of carbon monoxide and hydrocarbons vary inversely with vehicle speed. It is desirable, therefore, to distribute the projected vehicle miles by speed. Two speed regimes are typically used, urban and rural. Urban travel is assumed to average 25 miles per hour, rural travel 45 miles per hour.

Historical distributions of travel are available on a state basis. From these distributions it may be possible to determine functional relationships which could be applied on a regional basis. Population density may be a good explanatory variable.

Another possibility is to use speed distributions presented in the state traffic forecasts each state must provide the Department of Transportation.

3.2.2.4 Commuting Patterns. The most difficult adjustment to the vehicle miles projections will be to allow for commuting across regional boundaries. Since the BEA regions have been drawn so as to minimize intercounty commuting, the vehicle miles projections for these regions probably do not require any adjustment for commuting; however, ideally commuting should be taken into account when disaggregating the BEA regional projections to counties and their reaggregation to AQCR's.

There appears to be no simple way to adjust the vehicle miles projections for intercounty commuting. For some metropolitan areas, empirical data on commuting patterns may exist which could be directly imputed into the emissions projection model. For most areas of the nation, however, such data will not exist in a useable form. It may be possible to use the information on trip lengths provided in the Nationwide Personal Transportation Survey, however, this would be a fairly tedious effort.

Because of the lack of a computationally simple method for projecting commuting patterns, it does not appear cost-effective at this time to estimate or project commuting patterns. Provision should be made, however, for directly inputing any known commuting patterns for a county into the projection model.

3.2.2.5 National-Regional Integration. The per capita stock of automobiles, the total stock and the age distribution should first be projected on a national basis. The next step would be to determine the distribution of the total national stock among the regions.

Annual data on the distribution of the automobile stock are available on a county basis. In order to account for the various factors which would influence this distribution at a given point in time and changes in these factors with time, it will be necessary to employ appropriate statistical procedures for combining cross section and time series data.

The use of analysis of covariance techniques in the problem of pooling cross section and time series data has now become a common practice in econometric work. Suppose we have data on N counties over

T periods of time. The model usually followed in pooling procedures is:

$$y_{ij} = \alpha_i + \sigma_j + \sum_{r=1}^{k} \beta_r x_{rij} + u_{ij}$$

$$(i = 1,2,\ldots,N;$$
$$j = 1,2,\ldots,T),$$

where the α_i are the county "dummies", σ_j are the time "dummies", and x_r the "covariates". An argument frequently made against the use of the dummy variable technique is that it eliminates a major portion of the variation among both the explained and explanatory variables if the between county and between time-period variation is large. In some cases there may also be a loss in the number of degrees of freedom available for estimating the sampling variance of the parameter estimates. In addition, it is seldom possible to give a meaningful interpretation to the dummy variables.

A second approach is to recognize possible correlations among the error terms of the model and, in conjunction with restrictions, account for these in order to increase the asymptotic efficiency of the estimates of the causal parameters. A third approach to combining cross section with time series data has been termed the components of error or variance components model. With this approach, the regression error is assumed to be composed of three independent components - one associated with time, the second with the cross section units and the third being an overall component variable both in time and cross sectional dimensions.

Wallace and Hussain[7] present an analysis of the error components model as an approach to combining cross section and time series data. Comparisons of generalized least squares and iterative estimates with those produced by analysis of covariance techniques are provided. Maddala[6] extends this approach by investigating some aspects of the analysis of variance components models that arise from the use of likelihood methods and the presence of lagged dependent variables as covariates. However, for all their efforts, Wallace and Hussain[7] concluded that covariance estimates compare fairly well with the other approaches that they investigated. Given that covariance estimates are easily obtained without the time-consuming iterative estimation procedures necessary for some of the alternative approaches, it appears that the covariance technique would be the most appropriate approach to combining cross section and time series data in estimating the regional air emissions model.

Using the covariance approach the regional per capita stock of automobiles equations can be related to national conditions in order to minimize any differences between the sum of the regional projections and the national projection. A possible form of the functional relationship is:

$$\frac{\Delta\left[\frac{SA}{P}\right]_{ij}}{\Delta\left[\frac{SA}{P}\right]_{j}} = \beta_1 + \beta_2 \frac{\Delta\left[\frac{Y}{P}\right]_{ij}}{\Delta\left[\frac{Y}{P}\right]_{j}} + \beta_3 \frac{\Delta L_{ij}}{\Delta L_j} + \alpha_j + \sigma_t \tag{7}$$

(i = 1,2,...,N regions;
j = t = 1,2,...,T time periods).

In this regression the relationship of a region's change in the stock of automobiles to the change in the national average depends not only on the covariates of change in the relationship of regional income per capita and population density to the change in the national averages but also on a variable α_i which is peculiar to the i^th region and on a variable σ_j which is specific to the t^th year.

3.2.2.6 Ease of Model Revision. The model would be easy to revise. The inputs would consist of exogenously estimated: automobiles per capita functions, survival probability function, vehicle miles by vehicle age function, and an urban/rural travel function. In addition, beginning period estimates of the stock of automobiles by age would be a primary input as would the BEA income and population projections and county land area data. Periodically, the equations should be reformulated using the latest data available.

3.2.2.7 Use for Sensitivity Analysis. The model should have the capability of shifting the values projected for any of the parameters on a percentage basis in order to determine the sensitivity of the emissions projections to the values of the model parameters. For example, it would be desirable to be able to shift the projected values of the per capita stock of automobiles a given percentage in a simple manner so that the sensitivity of the emissions projections to the projection of the stock of automobiles could be observed. Likewise, it would be desirable to be able to arbitrarily shift the retirement, average vehicle miles, and urban/rural travel functions in order to determine the sensitivity of the emissions projections to these variables.

3.2.2.8 Data Sources for Predictive Variables. Stock of Automobiles - The R. L. Polk Co. of Detroit, Michigan maintains automobile registration data on computer tape by county of registration. The data are for July 1 but can be adjusted to January 1 by subtracting new registrations.

Personal Income - The Regional Economics Division, Bureau of Economic Analysis, U.S. Department of Commerce maintains an annual personal income series on a county basis. The values are in current dollars and should be deflated using the GNP Implicit Price Deflator for Personal Consumption Expenditures. Future values for personal income are provided in the BEA projections for 10 year intervals. Values for the intermediate years can be obtained through interpolation.

Population - The Regional Economics Division, Bureau of Economic Analysis, U.S. Department of Commerce has historical county population estimates. Future values for population in the BEA regions are provided in the BEA projections which are for 10 year intervals. Values for the intermediate years can be obtained through interpolation.

Land Area - The City and County Data Book, U.S. Department of Commerce contains a list of the land area of all counties.

Automobile Retirement Function - The retirement function can be calculated from R. L. Polk data of automobile registrations by year model. It would be desirable to examine the function for several time periods in order to analyze its stability.

Average Annual Vehicle Miles Per Automobile - The U.S. Department of Transportation's Nationwide Personal Transportation Study has average miles per vehicle by year-model of automobile. The national averages are published in Report No. 2, April 1972, Annual Miles of Automobile Travel. Primary data from the survey are on computer tape and could be used to adjust the national average for regional variations.

3.2.3 Trucks

Trucks account for the greatest portion, after automobiles, of registered motor vehicles, 17 percent. In 1969 there were 17.9 million trucks registered of which 97 percent were gasoline-powered. The remainder were diesel-powered or used other special fuels. Buses are less than one percent of all motor vehicles.[8] About 18 percent of the buses are diesel-powered. Because they are a small source of emissions the most cost-effective approach may be to not include them in the projection model. If desired, however, they could be combined with trucks or treated in an analogous manner to trucks.

The objective of an emissions projection methodology for trucks is to provide a procedure for projecting vehicle miles by gasoline-powered trucks and fuel consumption by diesel-powered trucks since the emissions factors for gasoline-powered trucks are related to vehicle miles while emissions factors for diesel-powered trucks are related to fuel consumption.[5]

3.2.3.1 Truck Projection Model. The stock of trucks on both a total and per capita basis has increased quite regularly over the last 20 years as shown in Figures 7 and 8. The stock of all trucks can be projected in a manner similar to that used for automobiles. However, since there is a clear differentiation in the area of operation of light and heavy trucks it is necessary to project the truck size distribution. As shown in Table 2, light trucks are primarily operated locally whereas heavy trucks are most typically used for intercity transport.

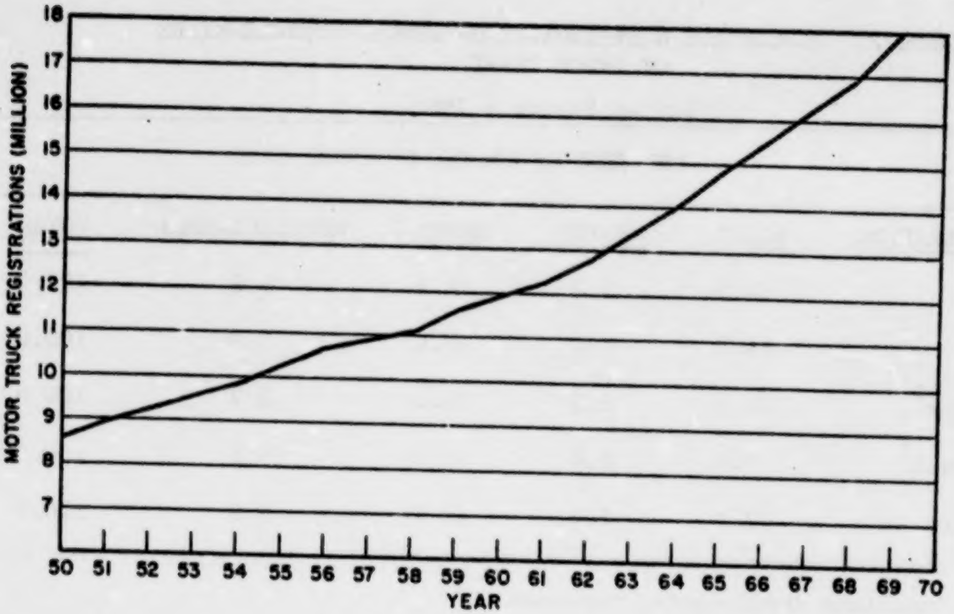

Figure 7. Stock of Trucks. (Source: Automobile Manufacturers Association, 1970 Motor Truck Facts)

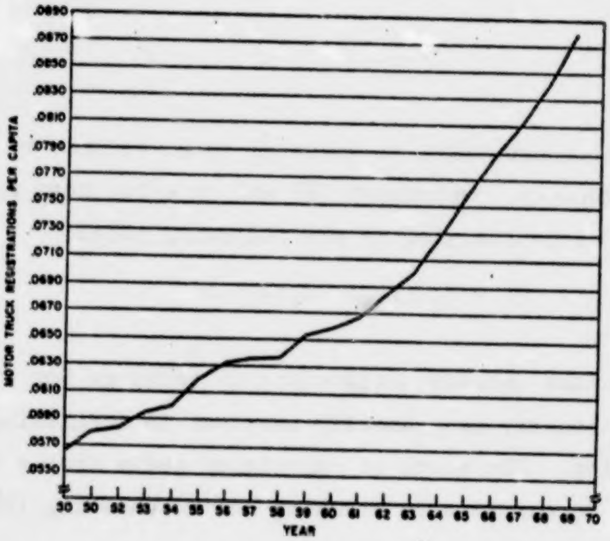

Figure 8. Stock of Trucks Per Capita. (Source: Automobile Manufacturers Association, 1970 Motor Truck Facts)

Table 2. PERCENTAGE DISTRIBUTION OF ANNUAL VEHICLE-MILES OF TRUCK TRAVEL

United States - 1963

	PER CENT OF TRAVEL BY TRUCK SIZE				
AREA OF OPERATION	LIGHT	MEDIUM	HEAVY	MISCELLANEOUS	TOTAL
Total	54.5	8.0	31.3	6.2	100.0
Local[1]	66.8	9.6	18.6	5.0	100.0
Intermediate[2]	27.8	8.3	55.2	8.7	100.0
Long distance[3]	5.9	0.8	82.5	10.8	100.0
Not reported	71.3	5.4	18.4	4.9	100.0

[1] Urban, immediate environment; farm use.

[2] Distances up to 200 miles.

[3] Distances over 200 miles.

Source: Truck Inventory and Use Survey, Vol. II, Table 27. 1963 Census of Transportation, U.S. Bureau of the Census, 1965.

The stock of all trucks (ST) is expected to be related to the area income, population density, employment (E) and an error term for the omitted factors (V) as represented by the following model:

$$ST = f_2 (Y, L, E, V) \qquad (8)$$

The BEA projections include projections of earnings for trucking and warehousing. This industry is primarily involved in furnishing local or long distance trucking. The stock of registered heavy trucks (SHT) can probably be related to earnings in trucking and warehousing (ETS) and an error term for the omitted factors (W).

$$SHT = f_3 (ETS, W) \qquad (9)$$

Expressing equations (8) and (9) on a per capita basis and assuming linear relationships, with the variables expressed in first differences to reduce the problems caused by serial correlation, we have the following model specification:

$$\Delta \frac{ST}{P} = b_1 + b_2 \Delta \frac{Y}{P} + b_3 \Delta L + V \qquad (10)$$

$$\Delta \frac{SHT}{P} = c_1 + c_2 \Delta \frac{ET}{P} + W \qquad (11)$$

The light and medium trucks can be obtained by subtraction:

$$SLT = ST - SHT \qquad (12)$$

The diesel share (SHTD) of all heavy trucks can be projected by extrapolating time trends:

$$\frac{SHTD}{SHT} = d_1 + d_2 T + Z \qquad (13)$$

Where T = time in years

Z = the error term which is the combined effect of the omitted factors

The age distribution for the stock of trucks can be projected in the same manner as for automobiles. Figure 9 shows the annual incremental and the cumulative retirement functions for all trucks. The number of trucks retired each year by model year is:

$$RT_{it} = h_i ST_{i(t-1)} \qquad (i = 1,2,3 \ldots n \text{ model years}) \qquad (14)$$

The total number of trucks retired is:

$$RT_t = \sum_{i=1}^{n} RT_{it} \qquad (15)$$

The number of new trucks purchased at time (t) can be obtained by subtraction.

$$XT_t = ST_t - ST_{t-1} + RT_t \qquad (16)$$

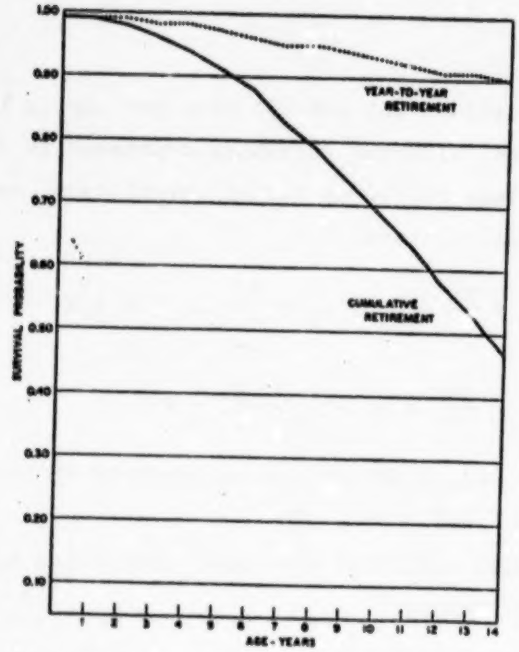

Figure 9. Truck Survival Probabilities.
(Source: Research Triangle Institute)

3.2.3.2 Vehicle Miles Projections. The average annual vehicle miles for trucks tend to decrease with increases in vehicle age and, for a given age, to increase as the size of the truck increases. Table 3 shows this relationship on a national basis. State data are available and can be used to adjust for regional variations.

3.2.3.3 Area of Operation. All trucks, other than heavy trucks, can be reasonably assumed to operate locally. Heavy truck mileage can be distributed on the basis of primary and urban road mileage in each region.

3.2.3.4 Vehicle Speed Distribution. Since there does not appear to be a significant difference in automobile and truck speeds, the same urban/rural speed distributions as determined for automobiles can be used for distributing the truck miles.

3.2.3.5 Data Sources for Predictive Variables. Most of the data sources applicable to the projections of automobile emissions also apply to the truck projections. The annual vehicle miles per truck, however, are available in the Census of Transportation.

Table 3. ANNUAL TRUCK MILES AND SIZE CLASS AND YEAR MODEL OF TRUCK: 1963

(Percent distribution of motor trucks)

Size class and year model	Total	Less than 5,000 miles	5,000 to 9,999 miles	10,000 to 19,999 miles	20,000 to 29,999 miles	30,000 miles or more	Not reported
	Distribution by truck miles						
All trucks	100.0	22.7	24.6	23.9	6.4	6.4	16.0
Light trucks, total	100.0	22.8	26.4	25.0	5.6	2.7	17.5
1962-63 models	100.0	6.0	20.5	39.2	14.1	6.1	14.1
1960-61 models	100.0	9.2	23.2	40.5	11.5	4.4	11.2
1955-59 models	100.0	18.6	30.3	29.6	4.9	2.5	14.1
1950-54 models	100.0	33.8	29.2	14.1	1.7	1.3	19.9
Pre-1950 models	100.0	39.2	21.7	7.9	0.9	0.9	29.4
Medium trucks, total	100.0	27.7	22.2	23.3	7.4	5.6	13.8
1962-63 models	100.0	6.8	16.4	35.8	15.7	16.0	9.3
1960-61 models	100.0	7.1	17.6	42.3	15.4	11.3	6.3
1955-59 models	100.0	17.6	27.4	31.3	9.3	6.4	8.0
1950-54 models	100.0	39.2	26.8	14.5	3.2	1.5	14.8
Pre-1950 models	100.0	50.4	15.6	5.2	1.0	0.9	26.9
Light-heavy trucks, total	100.0	27.3	23.0	21.3	8.3	7.4	12.7
1962-63 models	100.0	8.9	16.5	30.7	17.0	18.5	8.4
1960-61 models	100.0	11.6	19.8	32.3	15.6	14.9	5.8
1955-59 models	100.0	20.5	27.3	26.2	9.8	7.2	9.0
1950-54 models	100.0	39.8	26.5	13.4	2.9	2.2	15.2
Pre-1950 models	100.0	49.1	16.8	6.9	0.9	0.8	25.5
Heavy-heavy trucks, total	100.0	7.2	11.9	18.1	10.6	43.8	8.4
1962-63 models	100.0	2.4	5.9	15.3	9.0	59.3	8.1
1960-61 models	100.0	2.2	6.9	16.4	10.8	58.6	5.1
1955-59 models	100.0	6.1	12.5	19.6	12.2	43.0	6.6
1950-54 models	100.0	14.8	19.4	20.5	9.2	23.0	13.1
Pre-1950 models	100.0	25.0	20.5	14.9	7.2	11.0	21.4
Miscellaneous sizes	100.0	23.4	22.4	21.5	6.4	10.8	15.5

Source: RTI

3.3 Diesel Powered Motor Vehicles

3.3.1 General

Most diesel powered motor vehicles are trucks. To a lesser extent, however, buses are also diesel powered. It appears most cost-effective to project emissions from diesel trucks since their number is about eight times greater than that for buses. The methodology for projecting the stock of diesel trucks was set forth above. Since almost all diesel trucks are in the heavy size category the national projections of emissions should be projected in the same manner as for heavy gasoline trucks.

Relationships between the number of diesel trucks and the quantity of diesel fuel consumed can be established from the data presented in the American Petroleum Institute publication, Petroleum Facts and Figures.

3.4 Aircraft

3.4.1 General

Aircraft are propelled by emissions emitting gasoline-powered reciprocating engines and jet fuel-powered turbine engines. Aircraft emissions vary by the type of aircraft and number of engines.

Aircraft emissions factors are based on a landing-takeoff cycle (LTO). The LTO cycle used to develop emissions factors includes all the typical pre-takeoff ground operations, takeoff, climb to 3,500 feet, approach from 3,500 feet, and touchdown. The objective of an emissions projection methodology for aircraft is to provide a procedure for projecting, first on a national basis and subsequently on a regional basis, the number of LTO cycles by type of aircraft.

In 1969 there were 11,050 airports on record with the Federal Aviation Administration (FAA), of which 38 percent (4,155) were publicly owned. The remainder (6,895) were privately owned.[9] However, only a small percentage of the public airports, those with FAA air traffic control facilities, account for virtually all of the air carrier traffic and the greatest majority of the general aviation traffic. In 1969 there were 328 such airports. By 1971 the number had risen to 346.[10]

The trend in operations at the airports with FAA controlled towers is upward, growing about 7.4 percent annually. An "operation" is a landing, takeoff or missed approach and, therefore, must be divided by two (2) to get the number of LTO cycles. All of the air carrier traffic is itinerant, while about half the general aviation and military traffic is itinerant, the remainder being local.

Airport activity is greatest in the nation's population centers. The areas served by the air carriers have been divided into air traffic hubs (large, medium, small, and nonhub). Figure 10 shows the location of the air traffic hubs. About 38 percent of all itinerant operations are accounted for by the 22 large hubs, 20 percent by the 38 medium hubs, 22 percent by the 86 small hubs and 16 percent by the approximately 200 non hubs with FAA traffic control towers. In selecting an aircraft emissions projection methodology it will be most cost-effective to

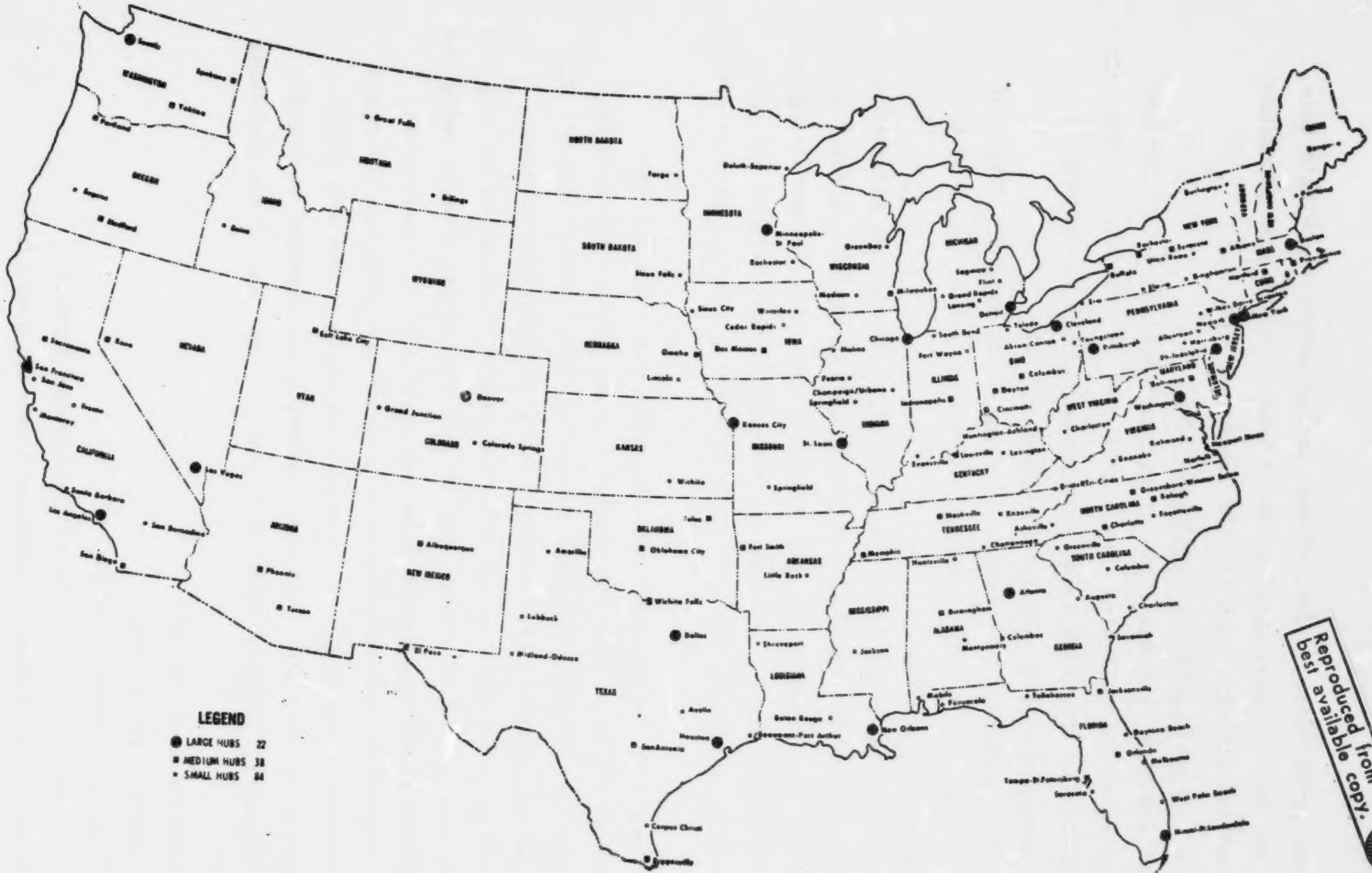
Seattle
WASHINGTON
Spokane
Yakima
Portland
OREGON
Eugene
Medford
IDAHO
Boise
Great Falls
MONTANA
Billings
WYOMING
NORTH DAKOTA
Fargo
SOUTH DAKOTA
Sioux Falls
Sacramento
Reno
NEVADA
San Francisco
San Jose
Fresno
Monterey
CALIFORNIA
Santa Barbara
Los Angeles
San Bernardino
San Diego
Las Vegas
Salt Lake City
UTAH
Denver
Grand Junction
COLORADO
Colorado Springs
ARIZONA
Phoenix
Tucson
Albuquerque
NEW MEXICO
El Paso
NEBRASKA
Omaha
Lincoln
KANSAS
Wichita
OKLAHOMA
Tulsa
Oklahoma City
Amarillo
Lubbock
Midland-Odessa
Wichita Falls
Dallas
TEXAS
Austin
San Antonio
Houston
Corpus Christi
Brownsville
Duluth-Superior
MINNESOTA
Minneapolis-St Paul
Rochester
Sioux City
Waterloo
Cedar Rapids
IOWA
Des Moines
Kansas City
MISSOURI
St. Louis
Springfield
Fort Smith
ARKANSAS
Little Rock
Shreveport
LOUISIANA
Baton Rouge
Beaumont-Port Arthur
New Orleans
MISSISSIPPI
Jackson
Memphis
WISCONSIN
Green Bay
Madison
Milwaukee
Chicago
Moline
Peoria
Champaign/Urbana
Springfield
ILLINOIS
MICHIGAN
Saginaw
Flint
Grand Rapids
Lansing
Detroit
South Bend
Fort Wayne
INDIANA
Indianapolis
Evansville
Toledo
Cleveland
Akron-Canton
OHIO
Columbus
Dayton
Cincinnati
Huntington-Ashland
Louisville
Lexington
KENTUCKY
Nashville
Knoxville
TENNESSEE
Asheville
Chattanooga
Huntsville
Birmingham
ALABAMA
Montgomery
Mobile
Pensacola
Atlanta
Columbus
GEORGIA
Augusta
Savannah
Tallahassee
Jacksonville
FLORIDA
Daytona Beach
Orlando
Melbourne
Tampa-St.Petersburg
Sarasota
West Palm Beach
Miami-Ft.Lauderdale
Greenville
SOUTH CAROLINA
Columbia
Charleston
NORTH CAROLINA
Greensboro-Winston Salem
Raleigh
Charlotte
Fayetteville
Bristol-Tri-Cities
VIRGINIA
Richmond
Roanoke
Norfolk
Newport News
WEST VIRGINIA
Charleston
Washington
Baltimore
MARYLAND
DELAWARE
Philadelphia
NEW JERSEY
Newark
New York
PENNSYLVANIA
Pittsburgh
Youngstown
Erie
Elmira
Allentown
Harrisburg
Wilkes-Barre-Scranton
Buffalo
Rochester
Syracuse
Utica-Rome
Binghamton
Albany
NEW YORK
Burlington
VERMONT
NEW HAMPSHIRE
MASS.
Boston
CONN.
Hartford
Providence
MAINE
Bangor
Portland
LEGEND
● LARGE HUBS 22
▪ MEDIUM HUBS 38
• SMALL HUBS 84

Figure 10. Air Traffic Hubs. (Source: Department of Transportation, Federal Aviation Administration, *Airport Activity Statistics*)

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confine the projections to the 346 most active airports. Within this total it may well be desirable to have a less sophisticated procedure for the smaller airports than for the larger airports.

3.4.2 Aircraft Activity Projection Model

There are three general types of aircraft activity: air carrier, general aviation and military. The air carrier activity is for-hire air transportation by trunk, regional or commuter airlines. General aviation consists of business and pleasure aircraft.

The air carrier fleet consists of about 2,700 aircraft (1970) of which 92 percent are turbine powered. Most of these are 2, 3 or 4 engine turbojet aircraft.

The general aviation fleet consisted of about 131,000 aircraft in 1970, about 95 percent of which are reciprocating engine powered. Most of these are single-engine (83 percent); the remainder are multi-engine, primarily twins. About 2 percent are turbine powered, almost all of which have two engines. The remaining aircraft are helicopters or other types.

Ten year national forecasts of itinerant and local aircraft operations at airports with FAA Traffic Control Service are developed annually by the Office of Aviation Economics, FAA. These forecasts will provide good national control totals for any regional projections.

National projections beyond 1980 can be developed either by simply extending the historical trends and ten year FAA projections, by using the more sophisticated technique of relating the aircraft activity to expected population and income growth or by simply using the forecasts to be released by the Aviation Advisory Commission at the end of 1972.

Regional projections of aircraft activity are provided by the FAA for approximately 1000 airports which meet at least one of the following criteria:

- existing tower airport
- candidate for a tower
- 50 or more based aircraft
- receives certificated route air carrier service
- 20,000 or more general aviation itinerant operations.

The distribution of operations by type of aircraft can be projected for large airports by analyzing current air carrier service in terms of the type of aircraft used and the routes flown. Future aircraft types are forecasted by the FAA and can be allocated to the airport. An example of such an approach is shown in the FAA publication Aviation Demand and Airport Facility Requirement Forecasts for Large Air Transportation Hubs Through 1980. For smaller airports served by air carriers it can probably be reasonably assumed that all the aircraft are twin-engined. The distribution can be based on FAA's projection of fleet composition.

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SECTION 4

PROJECTING EMISSIONS FROM AREA SOURCES AND FOSSIL-FUELED ELECTRIC GENERATING PLANTS

4.1 Introduction

The term "area sources" refers to those sources of emissions that are widespread and relatively evenly distributed throughout a region in such a way that the pollution they produce forms a ubiquitous pattern. This pollution results from fuel combustion for residential, commercial, institutional, and industrial heating. The pollutants involved are primarily hydrocarbons resulting from less than perfect combustion of the fuel, sulfur oxides resulting from the oxidation of the sulfur in the fuel, oxides of carbon and nitrogen formed in combustion, and particulates released with the exhaust gases. The quantities of these pollutants formed depend on the quantity of fuel burned, its ash and sulfur content, and the type of burner employed.

The problems associated with projecting emissions from steam-electric plants is discussed in this section because, although they are point sources, they have many of the characteristics of other stationary fuel combustion sources. Discussion of the appropriate methodology follows the analysis of area sources.

There are two general approaches that may be taken to projecting area source emissions. One is to estimate fuel consumption for each type of source and the other is to identify the number and type of burners in use and the fuel consumed in them. The second approach provides the most accurate estimates of emissions, but involves more complex and detailed calculations. A study[3/] performed for EPA by the Walden Research Corporation in 1971 followed this method and produced results apparently superior to previous studies. However, continuous use of this method requires use of data that are not readily available. The fuel consumption approach, on the other hand, uses data that are quite easily obtained from regularly published sources. Estimates based on projected fuel consumption may also be adjusted to reflect the influence of fuels availability and prices, and may be improved by incorporating much of the data on burner use patterns developed in the Walden study.

[3/] John R. Ehrenfeld, et al., Systematic Study of Air Pollution From Intermediate-Size Fossil-Fuel Combustion Equipment. Contract No. CPA 22-69-85. Cambridge, Mass., Walden Research Corporation, July 1971.

It is the recommendation of this report, therefore, that the projection of area source emissions be based on fuel consumption patterns. The remainder of this section is devoted to a discussion of the model to be used for this purpose. The problems involved in construction of this portion of the overall model are less complex than those related to mobile or point sources and this discussion is, therefore, less extensive than is provided in Sections III and V.

4.2 Estimation of Fuel Consumption

Estimates will be needed of the consumption, by county, of coal, distillate oil, residual oil, and natural gas. Consumption of these fuels by State is reported annually by the Bureau of Mines in its Minerals Yearbook. The figures for fuel oil are also published by the journal Fuel Oil and Oil Heat each year, along with analyses of new and replacement burner installations and other information indicating heating trends. The Edison Electric Institute provides annual data by State on electric heating and several trade organizations in the gas field also have annual data series that are applicable. Although the classifications under which these sources report their data are not fully compatible, it is possible to construct quite accurate estimates of actual consumption of each fuel by residential, commercial (including institutional), and industrial users for recent years. These series permit analysis of the time series trends of fuel substitutions. RTI has used these data over the past four years as the basis for the estimates furnished to EPA for inclusion in the Economics of Clean Air reports.

Future demand for these fuels for heating purposes ten and twenty years from now will be determined by the growth of population and commercial and industrial activity and by the general trend of energy use for heating. Construction of these equations should present no conceptual difficulties.

4.3 Residential Heating

Residential heating plants may be divided into two general categories: those in buildings housing one to four families, which use a relatively small furnace or space heaters, and larger structures with large central heating plants that are similar in burner characteristics and emissions to heating units for commercial, institutional, and small-to-medium sized industrial heat and power boilers. For purposes of this analysis, the discussion of residential heating will be limited to structures housing four or less dwelling units. Larger residential units are combined with commercial and institutional units.

The fuels used for residential heating today are coal, distillate oil, and natural gas. The use of coal for this purpose has declined very sharply in recent years and is negligible in most areas. Within 10 years no significant quantity of coal will be used for residential heating except in those few locations where it is exceptionally economical, such as parts of Pennsylvania, West Virginia, Kentucky, Ohio, Illinois, and perhaps Minnesota and Montana. The specific counties in which coal may continue to be used will have to be identified for regional analysis. For the general model, however, coal can be considered negligible.

Number 1 and 2 distillate oil are primarily home heating fuels and are consumed in most counties. Natural gas is also important, but its use is restricted in some areas where pipeline distribution is not available. A substantial and growing percentage of home heating is also done with electricity and allowance must be made for this in estimating residential fuel use on the basis of population growth.

Residential heating requirements can be estimated on the basis of population and the average number of persons per family, which indicates occupied dwelling units. The average structure size (number of rooms per dwelling unit and units per structure) combined with the annual heating degree days for each region can be used to estimate heating requirements in Btu's. This in turn can be divided into shares for each fuel on the basis of market share trends adjusted for fuel availability, and expressed in units of each fuel consumed. When multiplied by appropriate emission factors a reasonable estimate of annual emissions from residential heating may be obtained. Among the variables involved, only population will be likely to change substantially over the projection period.

4.4 Commercial, Institutional, and Industrial Heating

An approach similar to that used for residential sources can be used in projecting emissions from the other heating sources, except that the basis would be employment rather than population. It may reasonably be assumed that the required heat input per commercial structure is proportional to the number of persons employed therein, and that the same is true for institutional establishments. These ratios can be calculated by region and projections of heating requirements in Btu's based on projected commercial and institutional employment. The fuel demand thus projected can be apportioned to fuel types in the same manner as residential fuel requirements.

In a similar manner the ratio of required heat per year per employee can be calculated for industrial plants by two digit SIC classifications and projected fuel consumption projected by industrial employment. In this instance, however, adjustments will have to be made by classifying industrial users into broad size ranges to reflect the emission characteristics of boilers of different sizes and further adjustments may have to be made to reflect trends in use of boilers of various types. Although these adjustments require considerable computations, they do not appear to interfere with the estimation methodology.

It should be noted that the method described above assumes that variations in building construction characteristics, heat loss through loading doors and other areas, the use of process heat for space heating, and other similar variations from plant to plant are successfully averaged out so that the resultant emissions estimates have acceptable error limits. This appears to be an acceptable assumption at this time.

4.5 Fossil Fueled Electric Generating Plants

The problems of projecting emissions from fossil fueled electric plants is given relatively little space in this report not because they are unimportant, but because, in comparison with the other sources covered, they present few difficulties. These sources are major sources of particulates and SO_x emissions especially, and of other pollutants as well. This has been so well documented elsewhere as to need no elaboration here.

A very large and detailed body of data is available from the reports of the Bureau of Mines and the Federal Power Commission providing information, by plant, on operation characteristics, structure, fuel consumed, and control of emissions. Similarly, detailed data on planned construction are available for 5 to 10 years into the future and some information on potential plant locations is available for more distant future dates.

Detailed analyses have also been made of the future demand for electrical energy and the probable patterns of production by many public and private authorities. Much attention is being given also to the problems of fuels availability and the effects this may have on future patterns of electricity production.

These data, when incorporated with the projections of fuel use for heating, will provide a firm basis for projections of emissions from electric generating plants.

SECTION 5

PROJECTING POINT SOURCES OF AIR EMISSIONS ON A REGIONAL BASIS

5.1 Introduction

The objective of this section is to define techniques and models for projecting point sources of air emissions on a regional basis. More specifically, the feasibility of this task is examined in terms of the location of emissions, total output and process type for each industry, and the relative effort required to make the projections. The significance of each point source relative to the background level of emissions for the average region is also examined. Specification of the data requirements and the major variables determining the regional projections of point sources of emissions are also provided.

5.2 Significance of Point Sources of Emissions

The point sources of emissions examined herein generate substantial quantities of pollutants as a result of the industrial processes involved. Some of these sources are substantially larger than others. The various pollutants from each source have been classified according to their relative significance, in order to provide the Environmental Protection Agency with one criterion for establishing priorities for projection modeling. Data availability, the difficulty of projecting output, location, and process type are other criteria that will be treated in following sections.

The point sources of air pollution emissions considered in this study are those that have been identified as being important contributors of one or more pollutants. Because they vary considerably in terms of their contribution to aggregate pollution, however, it is desirable to provide a measure of significance that can be used in determining priorities for phased development of projection models. Assignment of priority to some sources to be included in the early phases of the model may be based also on the availability of data and the relative effort required to project output, location, or process type for each industry.

The measure of significance employed in this study is the ratio of emissions from an industrial point source within an average metropolitan AQCR to the total emissions from non-industrial sources, expressed as a percentage. The calculations of these percentages, shown in Tables 4 through 7, are based on the analyses provided in 1970 by RTI[4/] of emissions by source for 298 metropolitan regions. These data were used because they provide the only available analyses of a large number of regions. The emission estimates reflect emission factors that are different from those now considered most accurate, but are nevertheless sufficiently accurate to reflect the relative significance of the sources measured.

The calculations of significance for each industrial source were made by finding the average emissions by pollutant for the plants covered in the 1970 data and dividing those figures by the average background (non-industrial) emissions for the regions involved.

There will also be non-metropolitan regions in the total regional projection model so that every county in the United States will be included in an air quality control region. Sufficient information is not available at the present time to determine emissions for the average non-metropolitan area. The background emissions for such an area would have the effect of making any point source in these regions more significant than it would be in a metropolitan region. The ambient air quality would probably still be superior in the non-metropolitan region, however.

The significance measure is at best a guide for setting priorities. There are weaknesses in the technique that limit its application to more complex tasks. For instance, there may be more than one establishment of a particular source type in an area and the emissions are additive. Serious polluters such as iron and steel plants and refineries tend to be clustered in particular regions. An establishment may be substantially larger than the average for that industry or it may be less controlled than most establishments in the industry. On the other hand, the region may be smaller than the average metropolitan area and this factor would make the point source more significant.

[4/] For a list of the 298 metropolitan areas and the emission estimates, see D. LeSourd, *et al.*, "Comprehensive Study of Specified Pollution Sources to Assess the Economic Effects of Air Quality Standards, FR-OU-534, Vol. I, Research Triangle Institute, Research Triangle Park, December 1970.

Table 4 contains the emissions by type from major sources for 298 metropolitan areas in 1967. Stationary fuel combustion includes steam electric power plants as well as heating plants and boilers. Most particulates originate from stationary fuel combustion and industrial process sources. Stationary fuel combustion also accounts for approximately two-thirds of sulfur oxide emissions and industrial process sources for about one-third. Mobile sources generate about 90 percent of hydrocarbon and carbon monoxide emissions. Petroleum refining and storage produces most of the hydrocarbons and carbon monoxide emissions from industrial point sources.

The second half of Table 4 consists of emissions for the average metropolitan area by type and source. These were calculated by dividing total emissions from all metropolitan areas by 298. The critical row in this table is total emissions from all sources excluding industrial processes. Emissions from the various point sources were divided by the entries in this row in order to calculate their significance.

Table 5 is a list of total emissions from each of the industrial process sources for 1967 in the 298 metropolitan areas. Particulates arise in many different industries, but the largest quantities come from the grain and feed industry, from the iron and steel industry, from the kraft pulp industry, and from asphalt batching plants. Each of the other types of emissions are found in a relatively small number of industries.

Table 6 lists the emissions from an average establishment for each point source. These were calculated by dividing the total emissions from the point sources in the metropolitan areas (Table 5) by the number of establishments in the metropolitan areas. Some establishments are much larger than the average and others are much smaller, so the averages shown may be distorted. The largest point sources of particulates on an average establishment basis are the iron and steel industry and the pulp and paper industry followed by cement plants and lime plants. The primary metals industries, petroleum refineries, and sulfuric acid plants are the major source of sulfur oxide emissions. The only point source of carbon monoxide is petroleum refining, which is also the major point source of hydrocarbons.

Table 4

EMISSIONS FROM ALL SOURCES FOR 298 METROPOLITAN AREAS AND FOR THE AVERAGE METROPOLITAN AREA
(Thousands of Tons Per Year)

	Particulates	SO_x	CO	HC
Total for 298 Metropolitan Areas				
Solid Waste Disposal	1,110	-	3,770	1,400
Stationary Fuel Combustion [1]	3,247	11,416	-	-
TOTAL	4,357	11,416	3,770	1,400
Industrial Process	4,601	5,156	7,520	1,412
TOTAL	8,958	16,572	11,290	2,812
Mobile Sources [2]	330	-	126,000	21,100
TOTAL	9,288	16,572	137,290	23,912
TOTAL EXCLUDING INDUSTRIAL PROCESS	4,687	11,416	129,770	22,500
Average Metropolitan Area				
Solid Waste Disposal	3.7	-	12.7	4.7
Stationary Fuel Combustion	10.9	38.3	-	-
TOTAL	14.6	38.3	12.7	4.7
Industrial Process	15.4	17.3	25.2	4.7
TOTAL	30.1	55.6	37.9	9.4
Mobile Sources	1.1	-	422.8	70.8
TOTAL	31.2	55.6	460.7	80.2
TOTAL EXCLUDING INDUSTRIAL PROCESS	15.7	38.3	435.5	75.5

[1] Includes commercial-institutional heating plants, industrial boilers, residential heating plants, and steam-electric power plants.

[2] Nitrogen oxides are also emitted from mobile sources.

Source: D. LeSourd et al., Comprehensive Study of Specified Pollution Sources.

Table 5

INDUSTRIAL PROCESS SOURCES - ESTIMATES OF EMISSION LEVELS, 1967
(298 Metropolitan Areas)

	Quantity of Emissions (Thousands of Tons per year [1/]			
	Particulates	SO_x	CO	HC
Primary Metals				
Iron and Steel	1,100.0	-	-	-
Copper	-	2,140	-	-
Lead	-	200	-	-
Zinc	-	416	-	-
Aluminum	6.0	-	-	-
Petroleum Refining	80.0	1,750	5,300	810
Secondary Nonferrous Metals	9.8	-	-	-
Pulp and Paper	561.0	-	-	-
Chemicals				
Phosphate Fertilizer	-	-	-	-
Sulfuric Acid	63.6	650	-	-
Rubber Tires	1.2	-	-	n.a. [2/]
Coal Cleaning	64.7	-	-	-
Feed and Grain	1,674.0	-	-	-
Mineral Products				
Asphalt Batching	452.0	-	-	-
Cement	239.0	-	-	-
Brick Making	-	-	-	-
Lime	181.0	-	-	-
Gasoline Marketing and Bulk Storage	-	-	-	600

Source: D. LeSourd, et al., Comprehensive Study of Specified Pollution Sources.

[1/] Emissions abbreviated are: particulates (Part.), sulfur oxides (SO_x), carbon monoxide (CO), hydrocarbons (HC). Blanks in the table indicate the emission levels meet the applicable regulation or that emissions are negligible or do not exist.

[2/] Not available.

Table 6

AVERAGE EMISSIONS FROM EACH POINT SOURCE, 1967
(Thousands of Tons Per Year)

	Number of Establishments	Particulates	SO_x	CO	HC
Primary Metals					
Iron and Steel	134	8.20	-	-	-
Copper	10	-	214.0	-	-
Lead	4	-	50.0	-	-
Zinc	9	-	46.2	-	-
Aluminum	14	0.40	-	-	-
Petroleum Refining	199	0.40	8.8	26.6	4.1
Secondary Nonferrous Metals	583	0.02	-	-	-
Pulp and Paper	81	6.90	-	-	-
Chemicals					
Phosphate Fertilizer 1/	155	0.02	-	-	-
Sulfuric Acid	180	0.40	3.6	-	-
Rubber Tires	54	0.02	-	-	-
Coal Cleaning	256	0.30	-	-	-
Feed and Grain 2/	6,253	0.30	-	-	-
Mineral Products					
Asphalt Batching	1,064	0.40	-	-	-
Cement	138	1.70	-	-	-
Brick Making	301	-	-	-	-
Lime	113	1.60	-	-	-
Gasoline Marketing and Bulk Storage	14,998	-	-	-	-

1/ Elemental phosphorus and phosphate fertilizer emissions have been combined.

2/ Handling and milling.

Source: RTI

Table 7 contains the percentages that emissions from average point sources are of background emissions for the average metropolitan area. Table 7 indicates the importance of a particular point source if there is one and only one average size establishment present in the average size metropolitan area. If any of these conditions do not hold, the significance will be larger or smaller. Given these limitations, the analysis shows that there are a relatively small number of point sources that are highly significant as a percentage of background emissions for the average metropolitan area. Particulates from the typical iron and steel establishment and from the typical pulp and paper plant are both more than 40 percent of the average metropolitan area's background emissions of particulates. The average cement plant and the average lime plant each produce about ten percent of total emissions for the average metropolitan area. None of the other point sources of emissions are more than 2.5 percent of the average metropolitan area. Sulfur oxide emissions are very significant for copper, lead and zinc and relatively significant for petroleum refineries and sulfuric acid plants. The average petroleum refining establishment also generates about five percent of the total emissions of carbon monoxide and hydrocarbons for an average metropolitan area.

5.3 Projection Requirements

5.3.1 Expected Changes in Point Sources of Air Emissions

Some critical factors in projecting regional air emissions from point sources are the location of the point sources, total production for each source, and the production process used. Table 7 is a list of the point sources together with expected changes in the location, production and process types in each of these industries. The "no" column is checked when virtually no change is expected in any of the three aspects. The substantial column under "yes" is checked when substantial changes are expected or when the production process is likely to be a critical factor in projecting regional air emissions.

The first important factor in projecting regional air emissions is location. Many of the industries are resource based; that is, their location is dependent upon a source of raw materials. The location of some of the other industries are proportional to the distribution of the

Table 7

EMISSIONS FROM AVERAGE POINT SOURCE AS A PERCENTAGE OF BACKGROUND EMISSIONS FOR THE AVERAGE METROPOLITAN AREAS[1/]

(Percent)

	Partic.	SO_x	CO	HC
Primary Metals				
Iron and Steel	52.2	-	-	-
Copper	-	558.7	-	-
Lead	-	130.5	-	-
Zinc	-	120.6	-	-
Aluminum	2.5	-	-	-
Petroleum Refining	2.5	23.0	6.1	5.4
Secondary Nonferrous Metals	0.1	-	-	-
Pulp and Paper	43.9	-	-	-
Chemicals				
Phosphate Fertilizer	0.1	-	-	-
Sulfuric Acid	2.5	9.4	-	-
Rubber Tires	0.1	-	-	-
Coal Cleaning	1.9	-	-	-
Feed and Grain	1.9	-	-	-
Mineral Products				
Asphalt Batching	2.5	-	-	-
Cement	10.8	-	-	-
Brick Making	-	-	-	-
Lime	10.2	-	-	-
Gasoline Marketing and Bulk Storage	-	-	-	0.05

[1/] Background emissions include stationary fuel combustion and mobile sources.

Source: Tables 4 and 6.

Table 8

EXPECTED SIGNIFICANT CHANGES IN THE LOCATION, PRODUCTION, AND PROCESS OF EACH POINT SOURCE, 1967-1980

	Location			Production			Process		
	No	Yes		No	Yes		No	Yes	
		Minor	Subst.		Minor	Subst.		Minor	Subst.
Primary Metals									
Iron and Steel		X				X			X
Copper	X				X		X		
Lead	X			X			X		
Zinc	X				X		X		
Aluminum		X				X			X
Petroleum Refining		X			X			X	
Secondary Nonferrous Metals		X				X	X		
Pulp and Paper		X			X			X	
Chemicals									
Phosphate Fertilizer		X			X				X
Sulfuric Acid			X		X			X	
Rubber Tires		X			X		X		
Coal Cleaning		X			X				X
Feed and Grain		X			X			X	
Mineral Products									
Asphalt Batching		X			X		X		
Cement		X			X			X	
Brick Making		X			X				X
Lime		X				X			X
Gasoline Marketing and Bulk Storage			X			X		X	

population or of general economic activity. The only industry among the point sources that is not either resource based or determine by the distribution of population is rubber tires. The substantial column is also checked for phosphate fertilizers, sulfuric acid and gasoline marketing and bulk storage. Phosphate fertilizer is checked because of the difficulty in distinguishing between plants that produce elemental phosphorus and those that manufacture only phosphate fertilizers. Sulfuric acid is checked because the location is likely to change in the near future due to new sources of sulfur arising from the control of air emissions. Gasoline marketing and bulk storage is checked because very little is known about the location and level of production of these establishments. Copper, lead and zinc are unlikely to change their location. All the other industries are subject to small changes in the location of establishments or in the relative shares of national output.

The second factor is the level of total production in the nation. National production may change substantially in the aluminum, iron and steel, secondary non-ferrous metal, and the lime industries. The production and consumption of aluminum is dependent upon a number of factors, especially its competitive position relative to steel and copper in many uses. Domestic production of iron and steel will be greatly affected by the size and composition of imports. The secondary non-ferrous metal industry is intricately dependent upon production of primary metals and upon the amount of scrap that is generated and collected. The lime industry has been growing rapidly due to changes in the type of furnace used in the steel industry, because of activities in the paper industry, and because of new uses for lime. Very little is known about the level of production of gasoline marketing by specific location.

The third factor in projecting point sources is the production process used. If more than one process is used, then the composition of output from these processes must be known, since emissions can vary significantly from one process to another. Production process considerations are very critical in iron and steel, aluminum, phosphate fertilizer, coal cleaning, brick making and lime. Other required process information is the presence or absence of a catalytic cracker in petroleum refining, the presence or absence of a lime plant or generating equipment in the pulp and paper industry, the percentage of P_2O_5 in the finished product for each phosphate fertilizer establishment, the type of operation in the feed and grain establishments, and the age of kilns in the cement industry. An important element in projecting emissions from gasoline storage is whether or not the tanks have floating roofs, though this factor can also be considered a control measure.

5.3.2 Additional Data Needs

Data are required on the location, the production level and the process used in each establishment. The type and efficiency of controls applied at each establishment are also necessary. If the Environmental Protection Agency does not provide information on controls, then these data will need to be collected for almost all industries (see Table 9).

Additional data from that already available will be needed on the location and production levels of phosphate fertilizer plants, feed and grain elevators and mills, coal cleaning plants, asphalt batching plants, lime plants, and brick making establishments. A large amount of detailed information will also have to be collected on gasoline marketing and bulk storage. This information may have to be collected directly from the companies involved or it may be available in publications that have not come to the attention of RTI.

Additional information on process types is required for the aluminum, petroleum refining, pulp and paper, phosphate fertilizer, coal cleaning, brick making, and lime industries. General industry averages will not be useful in making regional projections of air emissions because the establishments in a region may use one process or another but not the industry average.

5.3.3 Relative Efforts in Making Projections of Point Sources

The relative effort required in projecting four different aspects of point sources have been listed in Table 10, together with a column that combines all four of them into an average. This last column is not a simple average, but a judgmental weighting of the four aspects that comprise it. The four aspects are the number of establishments, their location, total production, and the production process.

Table 9

ADDITIONAL DATA NEEDS FOR PROJECT POINT SOURCES OF AIR EMISSIONS

	Location [1]	Process	Controls
Primary Metals			
Iron and Steel			
Copper			X
Lead			
Zinc			
Aluminum		X	X
Petroleum Refining		X	X
Secondary Nonferrous Metals	X		X
Pulp and Paper		X	X
Chemicals			
Phosphate Fertilizer	X	X	X
Sulfuric Acid			
Rubber Tires			X
Coal Cleaning	X	X	X
Feed and Grain	X		X
Mineral Products			
Asphalt Batching	X		X
Cement			X
Brick Making	X	X	
Lime	X	X	X
Gasoline Marketing and Bulk Storage	X		X

[1] Not only is the exact location of the establishment required, but also information about production at each establishment.

Table 10

RELATIVE EFFORT IN MAKING PROJECTIONS OF SELECTED ASPECTS OF POINT SOURCES

Industry Effort[1]	Number[2]			Location			Production			Process			Combined		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Primary Metals															
Iron and Steel		X				X			X			X			X
Copper	X			X			X			X			X		
Lead	X			X			X			X			X		
Zinc	X			X			X			X			X		
Aluminum	X			X					X			X			X
Petroleum Refining		X			X			X			X				X
Secondary Nonferrous Metals			X		X				X	X					X
Pulp and Paper	X				X			X			X				X
Chemicals															
Phosphate Fertilizer		X			X			X				X		X	
Sulfuric Acid		X				X		X			X				X
Rubber Tires	X				X		X			X			X		
Coal Cleaning			X			X		X				X			X
Feed and Grain			X			X		X							X
Mineral Products															
Asphalt Batching			X			X		X		X					X
Cement		X			X			X			X			X	
Brick Making			X		X		X				X			X	
Lime		X				X			X			X			X
Gasoline Marketing and Bulk Storage			X			X	X	X			X				X

1/ Relative effort is defined as: 1 = easy, 2 = moderate, and 3 = difficult.

2/ Defined as: 1 = less than 100, 2 = 100-200, and 3 = more than 200.

The effort required in making projections of point sources of air emissions is probably related directly to the number of establishments. Those industries in which the number of establishments is less than 100 have been rated at the number one level of effort, those industries with 100 or more but less than 200 have been rated as number two, and those industries with more than 200 establishments have been rated as number three. Only six industries have more than 200 establishments.

The effort required in projecting the location of the establishments is a function of expected changes in location as well as the number of establishments involved. The location of point sources of emission will require a three level of effort for seven industries, a two level of effort for seven industries, and a one level of effort for four industries. The one level of effort indicates that no new establishments are expected or that a complete list of establishments is available and is not likely to change very much. A three level indicates that quite a detailed analysis will be necessary in order to come up with a reliable projection of the location of establishments and production at each one. The two level requires an effort somewhere between one and two.

The effort of projecting the level of production also varies among industries. Three level of effort will be required in the iron and steel, aluminum, secondary nonferrous metal, and the lime industries. The remaining industries are about evenly divided between levels of effort one and two.

The fourth aspect in making projections of point sources is the production process used. There are only five industries in which a three level of effort will be required. The production process is not important in the copper, lead, zinc, secondary nonferrous metal, rubber tire, feed and grain, and asphalt batching industries. All the other industries fall into the number two level of effort.

The four aspects involved in making projections of point sources have been combined into a single figure based on judgment. The reason that a simple weighted average cannot be used is that a level two effort in one aspect may not be equivalent in terms of man-months to level two efforts in another aspect. Therefore, this final number is based upon RTI's best judgment as to the degree of effort required. Projections can be easily made for the copper, lead, zinc and rubber tire industries, rated at the number one level of effort. Number two level of effort will be required for the phosphate fertilizers, cement, and brick making industries. The number three level of effort will be required for the remaining industries. These ratings do not imply the relative amount of time that should be spent on making projections for each industry, but are a first approach to the relative amount of time required to make equally accurate and valid projections for each of the point sources. The next section will discuss all the factors that should be considered in deciding the amount of effort to be allocated to each point source.

5.3.4 Decision Criteria

Table 11 consolidates the information contained in the preceding tables. Relative significance appears in the first section. A check mark in a column indicates that the emission of a particular pollutant from the average establishment for that industry is greater than a certain percentage of the background emissions of that type pollutant for the average size metropolitan area. The levels of significance are one percent, five percent, ten percent, and 20 percent. All the figures in the one percent column are clustered between 1.9 and 2.5 percent. There are only 9 point sources in which the level of significance is greater than five percent for a particular pollutant.

The second section is data needs, divided into a low degree and a high degree of new data. There are only four industries in the low category, but three of them are at the five precent level of significance (copper, lead and zinc). High data needs can be interpreted as those not readily available from published sources (see Table 9 for details). The greatest need for information appears to be in the phosphate fertilizer, feed and grain and the sulfuric acid industries. The six industries of iron and steel, aluminum, petroleum, pulp and paper, coal cleaning and lime industries will require an intermediate level of additional data. Significant data requirements also exist for asphalt batching and gasoline marketing and bulk storage.

The third part of Table 11 is the section on relative effort. In general, the combined figure corresponds very closely to the average of the four aspects of the relative effort.

Table 11
Decision Table

	Significance				Data Needs		Relative Effort					Reliability of Emission Factors	
	>1%	>5%	>10%	>20%	Low	High	No.	Loc.	Prod.	Proc.	Comp.	Yes	No
Primary Metals													
Iron and Steel				X			2	3	3	3	3	X	
Copper				X	X		1	1	1	1	1	X	
Lead				X	X		1	1	1	1	1	X	
Zinc				X	X		1	1	1	1	1	X	
Aluminum	X					X	1	1	3	3	3	X	
Petroleum Refining	X	X		X		X	2	2	2	2	3		X
Secondary Nonferrous Metals						X	3	2	3	1	3		X
Pulp and Paper				X		X	1	2	2	2	3		X
Chemicals													
Phosphate Fertilizer						X	2	2	2	3	2		
Sulfuric Acid	X	X			X		2	3	2	2	3		
Rubber Tires					X		1	2	1	1	1		X
Coal Cleaning	X					X	3	3	2	3	3		
Feed and Grain	X					X	3	3	2	1	3		
Mineral Products													
Asphalt Batching	X					X	3	3	2	1	3		X
Cement			X		X		2	2	2	2	2		
Brick Making						X	3	2	1	2	2		
Lime			X			X	2	3	3	3	3		
Gasoline Marketing and Bulk Storage						X	3	1	3	2	3		

1/ Defined as emissions from the average point source as a percentage of total emissions for the average metropolitan area for 1967 emissions. There is one check for each type of pollutant emitted.

The fourth part of the table is the reliability of the emission factor. Because of differences in production levels, process types and controls, the emission factors for some industries contain a wide margin of error. It is generally not reasonable to expend a large degree of effort in projecting an industry whose emission factors may be off by 50 or 100 percent.

The decision on the amount of time and money to be allocated to each industry is a choice for EPA to decide. The four categories of significance, data needs, relative effort, and emission factor reliability should be an aid in this decision. However, EPA personnel may have other insights into the importance of each as a source of emissions and also of the degree of difficulty in making regional projections for each of these sources. A particular point source may be relatively insignificant in terms of the total region but very significant in the area immediately surrounding it.

5.4 Review of Point Sources of Emissions

In this section each of the point sources of emission will be briefly analyzed. There is an appendix for each industry in which the industry is examined in greater detail.

Iron and Steel--The iron and steel industry is a very substantial emitter of particulates and fluorides. There were 134 establishments in 1967, but 35 of them account for more than half of the value of shipment in the industry. The critical elements in projecting this industry will be to project total domestic output by product and to allocate the share of output to each establishment. The production process used in each establishment also has to be projected as does the coking operation. The combined relative effort is level three.

Copper--Copper smelters are very substantial emitters of sulfur oxides in the areas in which they are located. There are only 10 copper smelters in metropolitan areas though there are some in non-metropolitan areas as well. The projection of this industry's output will require an examination of imports and recycling. Allocation of output by region will call for a look at possible new locations. The combined level of effort is one.

Lead--The lead industry is a substantial emitter of sulfur oxides. Demand is not growing and is likely to shrink in the future. Regional allocation of output will be affected by possible closures. The data needs and relative effort required to project the industry are both relatively low.

Zinc--The zinc industry is also a substantial emitter of sulfur oxides and like lead and copper, consists of a small number of establishments. Little additional data will be required nor is information on process type required. Projection of demand is the primary task. Distribution of domestic production will have to take closures into consideration.

Aluminum--Aluminum smelters are minor emitters of particulates and very substantial emitters of fluorides. There were 14 establishments in metropolitan areas in 1967. The primary task will be to project total demand for and domestic supply of the product. Attention will have to be given to be given to possible new locations when allocating total output on a regional basis. The combined level of effort is three.

Petroleum Refining--Petroleum refineries emit significant amounts of particulates, carbon monoxide and hydrocarbons and very substantial amounts of sulfur oxides. Projections of demand can probably be taken from the section dealing with mobile sources. The role of imports will affect domestic production, and greatly influence the location of refineries. Data are necessary on the presence of catalytic crackers as this greatly influences the amount of emissions. The level of effort required for this industry is three.

Secondary Nonferrous Metals--The secondary nonferrous metals industry is a small emitter of particulates on an establishment basis. There are, however, nearly 600 establishments and thus, if there are a number of them in one area, the emissions from them may be significant. Additional data will be required on the location and production level of each establishment in order to make accurate and reliable projections. The amount of scrap to be recylced is a major determinant of total output. The relative level of effort for making projections in this industry is three.

Kraft (Sulfate) Pulp Industry--The pulp and paper industry is a very large emitter of particulates on an establishment basis. There are 81 sulfate mills in metropolitan areas as well as sulfite and mechanical process mills. Data are necessary on the production level of each establishment and on the process used. Recycling will influence total output and new mills will help determine the regional allocation among existing plants. The combined level of effort in this industry is three.

Phosphate Fertilizer--The phosphate fertilizer industry consists of establishments that manufacture phosphoric acid and also those that manufacture phosphate fertilizer. This industry is a substantial emitter of fluorides and a very small emitter of particulates. There were 155 establishments in this industry in metropolitan regions in 1967 and so the absolute amount of fluoride emissions from each establishment is relatively low. Projections of total and regional production can be made readily but substantial amounts of data would be required in order to project emissions from each establishment. The combined level of relative effort is three.

Sulfuric Acid--The sulfuric acid industry is a significant emitter of sulfur oxides and a relatively minor emitter of particulates. There are about 213 sulfuric acid plants scattered around the country. The industry is changing rapidly due to the growing production of sulfuric acid as a by-product and regional projections of emissions will have to take this factor into account. The relative level of effort in this industry is three.

Rubber Tires--The rubber tire industry is a minor emitter of particulates. There are 54 rubber tire plants and only the older ones emit pollutants. Information is required on the emission controls on old plants in order to project emissions from this industry. The critical item in making projections is probably the projection of output from old establishments. The relative level of effort is one.

Coal Cleaning--The coal cleaning industry emits substantial quantities of particulates during the drying operation; although the amount varies with the process. Data need to be collected on the location, production level and processes used at existing coal cleaning plants. Total output can be readily projected and allocated regionally based on trends. Possible new locations will have to be examined for impact on emission levels in these areas.

Feed and Grain Industry--The feed and grain industry is a very large emitter of particulates. There are more than 6,000 establishments, but only a relatively small number are big emitters of particulates. Data are required on the production levels and number of establishments at each location in order to make projections. Total output can be readily projected as can the regional distribution once the necessary data are collected. The relative level of effort is three.

Asphalt Batching--Asphalt batching plants are significant emitters of particulates. There are more than 1,000 asphalt batching plants in metropolitan areas, distributed roughly in proportion to the population and level of construction activities. Additional data required are the location,production level, and controls at each establishment. Some plants are mobile, which further complicates the task. The combined level of relative effort is three.

Cement--Cement manufacturing plants are substantial emitters of particulates. There are 138 cement plants located in metropolitan areas. Good data are available on the location and production level of each of these plants, as well as the production process and age of the plant. The primary task will be to predict the location of the new, larger plants that are replacing existing plants.

Brick Making--Fluorides are emitted only from brick manufacturing establishments that use clay containing fluorides. It will be necessary therefore to survey all brick making establishments to determine the type of clay that each uses. Projection of total output and the regional distribution should be readily accomplished. The relative level of effort is two for this industry.

Lime--The lime industry is a substantial emitter of particulates. The amount of particulates emitted from lime plants is a function of the type of kiln used and the type of fuel. Data needs to be collected on an establishment basis for production levels, type of kilns, and the fuel used. Total output and the regional distribution of production are both substantial tasks.

Gasoline Marketing and Bulk Storage--The gasoline marketing and bulk storage industry is an emitter of hydrocarbons. There are about 30,000 establishments in 1967 and very little is known about their location, throughput, and tank types of controls. Because emissions from the average establishment are relatively small and the rate of emissions is declining, a series of assumptions may be the best way to allocate total throughput. Otherwise, an extensive data collection effort will be required.

5.5 Computer Model

The approach envisioned in making projections of air emissions from point sources is to make each of the point sources a submodel. The process type and production levels would be determined outside the model. The level of controls could be specified within or without the model. Proportional changes in the level of production could be made if this were desirable. Each submodel would have built into it the output in physical terms, the emissions associated with this output, and best estimates of the level of controls in the industry. There is little reason for the regional distribution of output among point sources to be determined within the large projection model.

The projection equations should probably be expressed in per capita terms so that total output, and regional output in some cases, will be a function of population. It will also be desirable, if possible to make total output a function of GNP (as well as the variable) so that this variable may be manipulated for the entire model. The model should be flexible enough to handle different assumptions about imports and import policy as this will be an important factor influencing total output in some of the industries. Finally, the model user should be able to assume a new plant for one or more industries in a region in order to see the effect on emissions.

SECTION 6

CONSTRUCTION OF THE COMPUTER MODEL

6.1 Scope of Work

The model for projecting air emissions must provide emission estimates at a national level. However, it must be possible to disaggregate national emission estimates by geographical region and polluter source.

There are three general sources of pollution: mobile sources, point sources, and area sources. Mobile sources are primarily motor vehicles and aircraft. Point sources include such things as solid waste disposal facilities, power generation facilities, petroleum refineries, pulp and paper mills, chemical, gasoline marketing and bulk storage, and food, agriculture and mineral products industries. Area sources include such things as residential and commercial heating plants.

The submodels used to compute emission estimates from these sources must reflect variations for a given type of emission due to such things as different industrial processes and different types of raw materials. Thus, in many uses it would not be possible to develop a single submodel for a given pollution source which would be applicable to all geographical regions.

6.2 Projection Strategy

6.2.1 General

There are two basic approaches to projecting air emissions: extrinsic methods and intrinsic methods. The extrinsic methods project the variable of interest. In other words, they extrapolate the variable based on historical trends. The intrinsic methods project related variables that predict the variable of interest. Often considerable effort will have been spent in projecting the related variables, i.e., the Bureau of the Census statistics on population. The intrinsic methods are normally preferred when adequate data are available for the related variables and when the variable of interest can be written as a function of several related variables. Both extrinsic and intrinsic methods would probably be used in developing a total national projection strategy.

A variation of an intrinsic method is the growth model. Using growth models to project the increase in air pollution emissions, an equation can be developed that expresses emission variables as a function of various demographic and socioeconomic factors whose values are currently known. Using this approach, estimates of the changes over time in the value of a given parameter as a function of a set of independent variables can be made. Alternatively, new values of the parameter at a given time can be calculated if values of the parameter at an earlier time are available. These alternatives are expressed mathematically as follows:

$$\frac{\Delta p}{\Delta t} = \frac{P_2 - P_1}{\Delta t} = f(X_1, X_2, \ldots, X_n) \qquad (1)$$

where:

$\frac{\Delta P}{\Delta t}$ = change in parameter P over time,

P_2 = value of emission parameter at time t_2,

P_1 = value of emission parameter at time t_1,

Δt = $t_2 - t_1$,

$X_1, X_2, \ldots, X_n$ = independent variables,

or the alternative expression

$$P_2 = P_1 + \Delta t(f(X_1, X_2, \ldots, X_n)) \qquad (2)$$

6.2.2 Operational Aspects: Model Methodology

The basic steps that would be involved in projecting national air emissions are the following.

First, national air emissions would be disaggregated into some logical set of components such as by region, by type of polluter and by type of pollution.

Second, an equation for each emission category would be developed using one of the methods identified above in Section 6.2.1, or a vector of data points would be defined and schemes for interpolation or extrapolation of these data would be determined. In general, the equations would consist of a set of coefficients (technological coefficients) identified by regression techniques and an associated set of independent variables. Both coefficients and variables would be supplied to the model by the user or would be defined internally by the projection model. The technological coefficients would be required for a given polluter source to reflect different geographical areas.

Third, the equations derived in step two would be used to calculate air emission for each logical component.

Finally, the emissions would be summed by different subcategories and/or totaled for national air emission estimates and the results reported. The equations for the different types of sources (point, area, and mobile) would be independent; thus, these emission estimates would be additive.

In addition to using the model to estimate total national emissions, subcategory emissions, or emissions from individual components, it should be possible to use the model to perform sensitivity analyses. With sensitivity analyses, variables which could contribute to a significant portion of the total emission would be identified. A sensitivity analysis should also be performed on the technological coefficients discussed earlier and the coefficients that require accurate estimation would be identified. The model could then be rerun and the effects of modifications to critical variables or coefficients determined.

6.3 Computer Model Characteristics

6.3.1 Introduction

In the previous section a basic mathematical approach to calculating air emissions is described. However, the mathematics must be incorporated into a comptuer model that itself must have a number of special features in order to provide users with a flexible working tool. For example, the model should be easy to use, provide a number of output options, allow for easy modifications of the data, and give clear error diagnostics. Recommended features of the computer model are discussed in the remainder of this section.

6.3.2 Model Input

Input data would include the type of run (such as a projection run or a catalog update run), information relating to various output and sensitivity analysis options, and model variables such as the year that the projection will be terminated, the population, or the gross national product.

The model should be structured so as to allow a user to spend a minimum amount of time learning input rules. In most existing models, data are entered with specified fields, for every variable, an input approach which is easy to program but which also results in many rules for input. As an alternative, each piece of data should be introduced by a descriptive attribute. In other words, each item of data would be named, and for input the value associated with the name would immediately follow it. This allows the data to be introduced in name/value pairs in any order and allows the user to omit input variables that are not needed for a given run. Variables that are not input can either be assigned default values by the model, based on national data estimates or ignored completely if the particular item is not critical to a given run. The name/value data entry technique provides an extremely flexible data entry procedure from the standpoint of the user, and yet input conversion is still straightforward from the standpoint of the programmer. The existence of the value for a model variable in the input should override catalog values or values that might normally be estimated by the model during a run.

A brief example of possible model input is as follows (each line represents one data card):

```
TYPE OF RUN:  PROJECTION
MODEL VARIABLES:  YEAR 1975 POP 2.33E8
     GNP  1.09E12    DWELLINGS  6.11E7
EMISSIONS:  A24  2.16E-1
SENSITIVITY:  GNP  .10
```

The technological coefficients discussed earlier are integral parts of the model equations and would not normally be considered a model input. These coefficients would be derived externally to the model and cataloged for latter use. During a run, the coefficients would be accessed by the descriptive attributes associated with each coefficient set (such as geographical region, etc.) and used in the computation procedures. However, catalog updates should be allowed either as part of a model run or on special update passes. The user should be allowed to replace complete sets of technological coefficients or to modify a set by introducing a percentage change in the entire set or possibly to a portion of the set.

6.3.3 Model Outputs

The key model output would be reports describing the emission estimates produced during the model run. These reports would include multiway tables (two-to three-way, at least), sorted lists, and key model results by geographical regions. It is felt that it is more important to provide the user with the ability to stratify the file and produce reports according to these strata than it is to provide the user with a large number of report options or report formats.

In addition to producing reports, the model should automatically produce a data set of all emission data computed in a given run. This data set would be maintained for n runs and then rewritten on the n+1 run. That is, a series of n data sets of results from the latest n runs should be maintained. The existence of these backup files immediately implies the need for output options that allow reports to be produced directly from a specified backup data set without recalculation of emission data. Data from the backup data sets could also be used as input to statistical analysis routines.

Another important model output is error diagnostics. In addition to the diagnostics produced by the operating system, the model should produce diagnostic messages related to the computer model and the data it processes. Whenever possible, the user should be able to read the error message from his printout rather than being forced to refer to an error code book. The model should look for and report invalid attributes, invalid ranges on certain variables, infeasible answers, and, whenever possible, logical inconsistencies between sets of answers or sets of input data. Insufficient error diagnostics could make the model difficult to use and seriously limit its effectiveness.

6.3.4 Model Documentation

The model documentation should consist of a technical report, a user's manual, and annotation of the computer programs.

The technical report should contain the mathematics used to calculate emissions and derivations and explanations of the mathematics and computation procedures whenever necessary.

The user's manual would contain procedures for making computer runs, descriptions of the various model options, input data formats, descriptions and examples of reports that could be produced by the model, system job control language used in making runs, data file formats, and any other information that is necessary for a user to effectively operate the computer model. To as great an extent as possible, the user's manual should be a brief "cookbook" type of report that is carefully indexed to allow easy access to the various sections.

The computer program annotation should contain enough information for a programmer to learn how the model operates and to make modifications to the computer code if needed. At a minimum this documentation should contain an overall English language description of how the computer program operates, at least one level of flowcharts, and a parameter list that defines and describes parameters which are internal to the computer code as opposed to the named input data variables. The computer program annotation should not be developed in its final form until the model has been thoroughly tested and is considered operational.

6.3.5 Other Considerations

6.3.5.1 Accuracy of Answers. The answers produced by the model should of course be as accurate as possible. However, when an answer is questionable, error bounds or estimates of a probable error should be provided. Numerical stability should be considered; however, it is not likely to become a critical consideration since the proposed methodology does not call for solving large sets of potentially ill-conditioned equations. Once the model is operational, the computation scheme for variables to which the model is found to be particularly sensitive should be reviewed for possible modification of the computational procedure in order to provide additional accuracy.

6.3.5.2 Hardware and Software. There do not appear to be any unusual hardware features that must be available in order to operate the proposed model. However, the model should be compatible with EPA's computer facility. This compatibility can be promoted by developing the model for an IBM 360 using secondary tape storage or 2314 disk file storage. Software compatibility can be promoted by developing the model in a standard version of a general purpose programming language such as FORTRAN or PL/1.

6.3.5.3 Flexibility in Altering the Computer Model Code. To as great an extent as possible, the model designers should develop the model in a modular fashion to facilitate modifications and extensions of the model. Persons who are not familiar with the overall model logic should be able to modify specific model routines (modules). Input required and output produced by the routine should be described as well as the function that the routine performs. Whenever possible, discussion of what is required to extend the routine or modify the routine should be included.

6.3.5.4 Model Test Procedures. Once initial runs have been made with the model and it is apparently debugged, the procedures that will be used to thoroughly test the model should be formally documented and the results of the acceptance test should be reported. Whenever possible these tests should include projections of earlier data to currently known data. If this cannot be done, model projections should be compared with projections obtained from other sources.

6.4 Computer Model Implementation

The project is divided into three phases. The first phase, the feasibility study, identifies the methodology that is required for projecting various emission categories. In the second phase the computer program will be written and a few industries selected for implementation. These industries will then be disaggregated by geography, and the technological coefficients will be obtained for each selected emission category. Finally, these selected industries will be incorporated in the computer program.

The third phase will incorporate the remaining emissions categories not included in Phase 2. At the completion of Phase 3 a total national emission estimate for all industries should be provided. It should be noted that most of the computer program will be developed in Phase 2 except possibly for a few minor details. In Phase 3 the variables and equation lists will be expanded to include the new emissions categories but no additional computer code will be required by the inclusion of these categories.

6.5 Validation of the Model

Any new model designed to estimate the future values of dependent variables can truly be validated only by testing it against actual empirical data for time periods for which the model was designed to provide projections. In other words, true validation can be provided only after sufficient time has elapsed for the operation of the model to be compared with actual data and its success in tracking the variables has been demonstrated enough times to remove most chance elements. Even then, the fact that a model tracks well does not prove that its logic is correct; only that it shows a high correlation with actual data.

A kind of preliminary validation can be accomplished, if the base year of the model is not the current year, by running the model for a year in which real data is available. In this instance, if the model is constructed on a base of 1970 and earlier data, the model could be run for 1972 and the results tested against available emission data for 1972, in selected AQCR's. Several dangers are inherent in this approach, however. One is that the model will be designed to provide 10 and 20 year projections and its ability to project with reasonable accuracy for 2 years would not ensure its validity in projecting for the longer period. Also, to serve as a test of validity it would be necessary that the emissions data be derived independently and not based on the same types of data and assumptions used in constructing the model.

The model could also be run backward to some earlier year and its estimates compared with available empirical data. However, since the model will be based on known trend data, a good fit with the past tends to show only that it expresses the past relationships with reasonable accuracy.

One other effort can be made to provide as valid a model as possible. That is, each of the data series used as inputs may be examined with great care for accuracy and for the assumptions used. Any model is only as good as its inputs.

SECTION 7

FEASIBILITY, CAPABILITY, AND LIMITATIONS

The discussion in previous chapters of this report have made it clear that an emissions projection model of the type desired by EPA is feasible. It has been determined that there is enough known about the present status of mobile, area, and point sources of air pollution emissions and their future growth patterns, as well as the theories of the economic determinants of regional growth to provide a sound basis for projections. Most of the essential data are available from Government and private sources, or can be interpolated or synthesized from available sources, thus minimizing the collection of new data series and the use of assumed values. The nature and structure of the required computer model has been examined and found to be conceptually feasible.

The model conceptualized in this study will project, for the tenth and the twentieth year from date, by county or AQCR, the number and operating size of each source category, and the resultant emissions at a prespecified level of control. This would represent the initial specifications of the total model. The sources included would be those described in Sections III, IV, and V of this report. Emissions would be estimated for the five pollutants discussed, i.e., particulates, SO_x, NO_x, hydrocarbons, and CO. The model would be so structured as to permit the addition of subroutines for additional industrial sources and additional pollutants. The model would also be capable of aggregating the emissions data to provide state and national totals by pollutant and by source category.

The accuracy of such projections at the county or AQCR level will depend primarily on the accuracy of forecasts of the location of new plants, of the rate of growth of production in each industry category, of the patterns of population growth and migration, and of the patterns of vehicle movements. Projections of any of these factors are necessarily subject to considerable error.

The rate of growth of production is now being estimated by many agencies, both within the Federal Government and by private university, consulting, and trade organizations and these provide a reasonable basis for estimates of the total output of each industry within this model. However, estimation of the future growth of production from the individual plants in an AQCR has much less basis. Firms may prosper and grow or fail to do so depending on the effectiveness of management decisions, degree of competition, and many other factors that cannot be included as variables in the proposed model. It will be necessary, in making emission estimates for AQCR's, to assume that each plant in an industry behaves as does the industry average, unless special information about geographical trends is available.

Plant closings and expansions can be predicted only very roughly. If closings are anticipated, it may be assumed that older plants will be the ones closed, but such an assumption is subject to exception. The expansion of existing plants and the location of new ones is even less determinable 10 and 20 years in advance.

The proposed model cannot, therefore, be expected to provide more than a general indication of possible patterns of the growth of emissions. Operation of the model to answer questions of the "What if..." form, with alternative values for the significant parameters can be useful to EPA, however. It will provide a means of quantifying the potential impact of hypothesized changes in industry emissions sources and of projecting a large scale picture of impacts of change that could occur in many regions simultaneously.

Emissions from areas will depend largely on population movements and to a lesser degree on industry location, although the two are obviously interrelated. Population movements are carefully studied by a number of agencies and have been projected with a limited degree of accuracy in the past. The 10 and 20 year estimates required for the proposed model will, however, be subject to substantial possible error. This will be especially true for small regions (AQCR's and even states) due to potential changes in the rate of population growth and, more importantly, to shifting patterns of urbanization and migration.

Mobile source emission estimates will be subject to the same limitations as area source estimates, since they are closely linked to population. In addition, it will be particularly difficult to project future commuting patterns and changes in transportation technology. Both of these factors may change quite rapidly and fundamentally, especially over a 20 year time span.

The model should be tested to determine the sensitivity of various parameters. It is probable that many of the variables discussed above will prove to be those which are substantially sensitive, so that small variations will significantly change the estimates of emissions for individual AQCR's. These should be subjected to independent analysis to insure maximum accuracy of data inputs.

Any predicative model should be regarded as providing conditional estimates of probable values of key variables, not absolute statements of what will happen. Models, therefore, should be used as aids to judgment and analysis. The proposed model can be run annually and continuously revised to incorporate improved estimates of any of its variables. Used in this way it should provide an excellent means for evaluating complex interrelationships influencing emission sources and prove useful for identifying potential future problem areas.

APPENDIX A

EVALUATION OF NATIONAL MODELS

1.0 THE OBERS PROJECTIONS

1.1 General Characteristics

The objectives of the program under which these projections were produced were to develop: (1) a regional economic information system covering both the past and the future, with provision for rapid data retrieval; (2) short, intermediate and long-term projections of population, economic activity and land use for the Nation and its subareas; and (3) special analytical capabilities. The information system and projections form an economic framework within which future economic needs for the development of the Nation's resources can be estimated. The analytical system provides a systematic procedure for quantifying the nature and magnitude of economic benefits and impacts resulting from specified types and scales of resource development.

The projections were developed by the Office of Business Economics (OBE), presently the Bureau of Economic Analysis (BEA), of the U. S. Department of Commerce, and the Economic Research Service and the Forest Service of the U. S. Department of Agriculture. The effort was sponsored by the United States Water Resources Council. The program was initiated in 1964. Projections of population, employment and earnings by State, water resources areas, 173 OBE economic areas, and the SMSA and non-SMSA portions of the OBE areas are scheduled for publication in the summer of 1972. Documentation of the projection methodology and preliminary projections of economic activity have been previously published by the United States Water Resources Council (U. S. Department of Commerce and U. S. Department of Agriculture, 1971).

The projections are basically developed by a computer model which projects the share of employment and earnings by industry sector in each of the 173 OBE economic areas. However, the projected trends of these shares are examined for consistency and reasonability and adjusted if necessary. In addition, a preliminary set of projections have been reviewed by designated officials in each of the 173 OBE regions. The final series of projections are being developed and will incorporate the results of these reviews. Thus, the OBERS projections have been developed by a combination of man and machine techniques.

1.2 Detailed Characteristics

The OBERS projections, like all projections, are conditional views of the future, conditional on the realization of the assumptions employed in their development and an extension of past relationships believed to have future relevance for the measure being projected. The projections are shaped by long-run or secular trends in the economy rather than by the cyclical fluctuations which characterize the short-run path of development. Assumptions, either explicit or implicit, which reflect this principle and which are inherent in the projections, are as follows (U. S. Department of Commerce and U. S. Department of Agriculture, 1971, pp. I-4, I-5):

1. Population growth will be conditioned by a substantial decline from the fertility rates of the 1962-1965 period;
2. Reasonably full employment will prevail at each of the projection points;
3. At projected dates, the economy is considered free of the disruptive effects of foreign conflict;
4. Stability will be maintained in the conduct of international trade;
5. Continued technological progress and capital accumulation will support a growth in output per man hour of 3 percent annually;
6. Development of new products will be accommodated within the existing industrial classification system;
7. Growth in output within the context of the existing industrial structure can be achieved with environmental balance although this may require control of energy resources, restriction of the use of pesticides and other chemical products, and encouragement of population dispersion; and
8. The historical trends in import/export activity are extended into the future except for agricultural exports which, though continuing to increase, will constitute a smaller share of U. S. production.

The OBERS projections deal exclusively with the supply side of economy. Implicit in the projections, however, is the assumption that sufficient demand will be generated by the private and public sectors to maintain a full employment level of economic activity.

The model is in no way an attempt to explain the process of economic growth and development. Rather, it begins with projections of national population and successively refines this total to the working age population, total labor force, civilian labor force, civilian employment, private civilian employment, hours worked per year per man, and gross product per man per hour. Projected Gross National Product results from the mathematical combination of these variables.

The foundation for all projections relating to the agriculture sector is projected national demands for food and fiber. These national estimates provide both the conceptual and quantitative control for other elements of the national agricultural structure and all regional distributions of production, value, employment, earnings, and land use. Of particular note is the fact that projections of agricultural product demands for domestic food use are based on the projected rates of population growth and per capita consumption with the latter related to projected levels of per capita personal income.

The overall system for preparing the economic area projections uses four separate models. Basic or export industries except agriculture are projected by a variation of the "shift-share" technique for regional industrial analysis. This technique distinguishes a proportional growth element and a differential growth element between a region and the Nation in each industry or income component from historical data and projects these elements into the future. Thus, employment (or earnings) in industry will grow faster (slower) in a particular region than in the Nation, due to that region's comparative advantage (disadvantage) in the production of that industry's output.

Mathematically the shift-share approach to projecting regional economic activity may be expressed as follows:

$$E_{ij}^{t} = (E_{io}^{t}/E_{io}^{x})\ E_{ij}^{x} + C_{ij}^{t}$$

The subscripts i and j refer to the i^{th} industry and the j^{th} region, respectively; the subscript o refers to a summation: when in the right hand position, it is the summation of the regions (= the Nation); when in the left hand position, it is the summation of industries (= total employment or earnings). The superscripts t and x refer to the projected and base periods, respectively. The term C_{ij}^{t} equals the difference between the level of employment or earnings attributable to the national growth rate of the industry and the regional level actually attained in the industry. The first term on the right hand side of the above equation is the proportional growth element; the C_{ij}^{t} then is called the share or regional share effect.

The causal factors associated with the C_{ij}^{x} terms are the essence of industrial location theory. One approach to projecting regional economic activity is to develop an econometric model which uses multiple regression techniques to "explain" the variations in the C_{ij} effect across regions for each industry in question. Such a model is currently under development at the BEA (U. S. Department of Commerce and U. S. Department of Agriculture, 1971, p. III-13), but was not used for the OBERS projections.[1/]

For the OBERS projections, a more simple method for projecting the C_{ij} term, one which is less demanding of the data but which makes maximum use of all presently available information, was employed. For each of the basic industries, a curve was fitted to each region's percent of the national total of earnings and employment (separately) for the selected years for which data are available. These curves were then extended into the future and values of the region's projected percentages in the target years were determined. Thus, the approach employed is actually a variation of "shift-share" analysis with the regional share effects calculated implicitly rather than explicitly.

[1/] The BEA model projects the share effect for each 50 industries. Presumably one of the reasons for the lack of acceptable results from this approach is the fact that substantial variations in locational factors may exist within these 50 categories. Accordingly, this approach may prove more satisfactory if the industry sectors are defined in more detail.

In order to project air emissions, it will be necessary to project industrial activity at the four-digit SIC level of detail for approximately 15 industries. Since there is a relatively small number of these industries and since their characteristics are relatively uniform within a four digit SIC category the feasibility of using a multiple regression approach to projecting the share component and thus the regional distribution of economic activity will be explored in the remaining efforts of this project.

Projected levels of agricultural production for each region are consistent with the availability of natural resources for agricultural use. They are based in part on the use of an interregional linear programming system which identifies a pattern of land use and geographic patterns of output with a minimum outlay of capital, labor and other economic resources. Employment and earnings in the local-service or residentiary industries in each area are projected on the basis of historically-developed relationships with the area's basic industry activity. Finally a consistent projection of regional population is developed by assuming this total to be a function of regional employment and income.

Preliminary projections are currently available from the OBERS system for selected time periods extending almost fifty years into the future: the years 1980, 1990, 2000, 2010, 2020. A final series of regional projections for each of these years is scheduled for completion in the summer of 1972.

The basic geographic areas for which the projections were developed are the 173 OBE economic areas which completely span the Nation. These areas are composed of groups of counties and were determined in such a manner that inter-area commuting from place of residence to place of work was minimized. In other words, the OBE areas are relatively self-contained. regions of economic activity, measured in terms of residence/work locations.

One disadvantage of this regional framework is that the OBE regional boundaries do not coincide with certain political and statistically defined areas, e.g. states and SMSA's. However, projections for the 173 areas have been subdivided into approximately 900 sub-sectors in order to provide projections for various geographic areas. The scheduled summer 1972 publication will contain projections for states, 20 water resources regions, SMSA's and the non-SMSA protions of each state and OBE region. Of particular note is the fact that population, personal income and earnings projections for 55 Air Quality Control Regions, established as of October 1969, have been developed within this regional projection system (U. S. Department of Commerce, 1970).

The OBERS system provides internally consistent projections of population, employment, personal income and earnings. Per capita personal income and earnings per worker are also provided, both in absolute terms and in U. S. relative indices. Both earnings and income are projected in constant 1967 dollars.

Employment projections are developed from historical data collected in the decennial census. The "persons engaged in production" employment series used in projections of the national industrial structure is conceptually consistent with other data series used in the overall projection effort and is therefore the proper series to use in projecting industry relationships. However, since this series is not available in the required geographical detail the projected national industry employment was converted to the Census employment concept.

Employment and earnings projections are available for each of the 173 OBE regions for 37 industrial groups, mostly consisting of two digit level SIC detail. However, projections for other geographic areas (e.g. water resources areas, air quality control regions) contain only employment totals. For all types of geographic area aggregations earnings for each of the sectors are provided.

The OBERS projections, as with any regional projection effort, require large amounts of somewhat detailed data. In the necessary compromise between theoretical adequacy and data availability in regional projection efforts, the BEA feels that the approach chosen is usually dictated by the types of data that are either available or can be developed within a reasonable expenditure of resources. As mentioned previously, their projection methodology confirms this belief.

The regional population and employment data series for the OBERS projections are obtained from the results of the decennial population censuses. The area estimates of personal income and earnings by industry sector are constructed from a wide variety of statistical information, consisting mainly of compilations by government agencies, although data are also drawn from numerous private sources. The income and earnings estimates were developed within the framework of the Commerce Department's official state estimates of personal income and are available annually on a county basis.

The current BEA data base within Regional Economics Division's Regional Information System consists of the following items:

Population	Decennial census totals by county for 1930, 1940, 1950, 1960.
Employment	Decennial census data for 1940, 1950, and 1960 for each of the 37 sectors for each of the 173 OBE economic areas. For the 173 areas, employment totals for the 37 sectors were estimated for 1966. County employment estimates for agriculture for 1962, 1965 and 1966. For 1967, 1968, 1969, and 1970 wage and salary employment by 2-digit SIC classification by county and by place of work are now available, although these data were not used for the current projection effort. In addition, estimates of self-employed persons in agriculture and non-agriculture industries are available by county for these years.
Personal income	County data through 1969 available classified into a variety of sources.
Earnings	County data through 1969 are available by 2-digit SIC category. From 1967, annual estimates of wage and salary income are available in 60-industry detail at the county level. However, for each of these series, much of the industry detail cannot be shown at the county level in order to avoid disclosure of confidential information.

1.3 Operating Procedures

The Regional Economics Division of the BEA plans to update these projections on a regular basis, hopefully every two years. Future projection efforts will of course benefit from an improved data base and projections procedures. In particular, the Division is planning to provide projections of employment in each of the 37 sectors for sub-OBE regions during the next projection cycle. They are also planning to improve the shift-share methodology for projecting regional economic activity.

These updating efforts will, of course, require a substantial amount of resources, most of which are related to updating the appropriate data bases. However, the Regional Economics Division seems to be committed to maintaining the data base, as a large portion of its staff of approximately 60 is continuously involved in this effort.

It is doubtful that the OBERS methodology as it now exists can be efficiently used in a sensitivity analysis model. In order to examine the effects of alternative assumptions, it would be necessary to generate a large amount of additional data and to perform numerous additional computer runs. For sensitivity analyses, it may be more appropriate to take the relatively aggregated output of the OBERS projections as fixed and perform the industrial and geographic sensitivity calculations within this framework.

1.4 Evaluation for EPA's Use

The OBERS projections provide an excellent set of consistent regional projections of population, personal income, and employment and earnings at an adequate degree of industrial detail. The projections are provided for a time-frame that falls within EPA's period of interest. Furthermore, despite the large amount of resources required, the Regional Economics Division of the BEA appears committed to updating the projections on a regular basis.

The primary disadvantage of the OBERS projections for the EPA's use is that the appropriate measures are not provided in the necessary detail to project air emissions. In order to project these emissions, some measure of output, measured in physical terms, by industrial sector is required, whereas the OBERS projections furnish only employment and earnings projections. However, it is felt that a proxy for physical output can be constructed by projecting the relationship of some output measure, such as gross product originating, to earnings for each industry sector, with both variables expressed in constant dollars.

As mentioned previously, the OBERS projections are based on supply factors only and do not explicitly include the effects of changes in demand patterns on the industrial composition of output and employment. However, in order to include demand factors in the projection methodology, various components of demand would have to be projected for each of the 173 OBE regions. In addition projections of trade flows among the regions would be required as all regions produce goods for export and import goods and materials from other regions. Projections of these measures would require a significant expenditure of resources, which would perhaps be more effectively employed in developing an improved basis for other components of the overall air emissions projection framework.

Finally, the OBERS methodology may be criticized in that it is essentially a trend projection technique. This is true to a certain extent, at least with respect to projections for the basic industries. However, the trend projections for these industries are modified by the judgment of both BEA staff and, if the current practice is continued, by knowledgable persons in the regions themselves. Again it appears that the necessary compromises with the available data have resulted in a projection methodology that does not contain all the features desired but one which, nonetheless, is acceptable for OAP's purposes.

Although it is difficult to evaluate the accuracy of the regional projections, the preliminary national projections of economic activity as developed within the OBERS framework have been compared with the BLS national projections for 1980 (see Section 6.0 of this appendix for a brief discussion of the BLS approach to developing projections). Although the two sets of projections were developed by different approaches, the national totals for 1980 were reasonably consistent, a finding which helps to justify the recommendation of the OBERS projections for the OAP's use.

Disaggregation of the OBERS projections to both the appropriate degree of industrial and geographic detail may not be so easily accomplished. However, a more promising approach may be to develop specific procedures for developing the detailed outputs required to project air emissions and to use the resulting measures within the framework of the overall OBERS projections.

In summary, the OBERS projections seem most appropriate of those evaluated for use by the OAP to project air emissions. They form a consistent set of projections of several key economic and demographic variables that can be input to the development of a more detailed procedure for projecting air emissions. Furthermore, the OBERS earnings projections, which can be obtained for a variety of county groupings, will be most useful in developing an index by which projections of physical measures of output can be obtained. Finally, since the OBERS projections constitute the basis for a long-range water resource planning effort it seems appropriate to provide the same basis for long-range projections and planning in the area of air emissions.

2.0 THE HARRIS MODEL

2.1 General Characteristics

The objective of this model is to forecast industry activity on a regional level along with other regional variables, including population, income, labor force and unemployment. It is assumed that there is a tendency for labor and capital to migrate in order to improve their returns. The migration of capital is explained with a set of industry location equations that predict the change in output by region. The migration of labor is explained by a set of population migration equations.

The forecasting model is being developed under the leadership of Dr. Curtis C. Harris, Jr., at the University of Maryland.[2/] The development was supported in part by a grant to the University of Maryland from the Economic Development Administration, United States Department of Commerce. At the present time, work is continuing under funding from the National Science Foundation.

The projections are developed by a computer model, which projects values for each of the regions and insures that they are consistent with separately derived national projections. Once the equations in the model have been developed and selected, the projections are generated by the computer model without any manual adjustment.

2.2 Detailed Characteristics

At the present time, the Harris model has not been used to make projections for a future year. Therefore, it is not possible to report on the assumptions that are used to develop the future projections.

[2/] Complete documentation of the Harris model is not available at the present time. Dr. Harris supplied draft chapters from two books, A Regional Forecasting Model and An Industry Location Model, which are based on the model building effort. The structure of the model is outlined in Harris (1970). A different type of model for projecting county economic activity, whose development was not completed, is documented in Harris and McGuire (1969). This latter model is based on the shift-share technique for projection regional economic activity.

The forecasting model starts by projecting the location of firms in each industry. The change in output of each industry sector is explained by two sets of variables: (1) input prices that firms face in each location, and (2) agglomeration variables that help explain location behavior that is not accounted for by prices. After output has been determined, then employment, population, earnings, and personal income are derived. Also, final demand sectors are projected--consumption. government expenditures, investment and foreign exports.

The model is recursive. The supply and demand data in year t are used to forecast variables for the year t + 1, then the forecasts are used as data to make forecasts for the year t + 2. Successive forecasts are developed in this manner until those for the target year are provided. In any given year, predetermined changes may also be made in the input data, such as changes in governmental expenditures.

An important set of variables used to determine the location of output is the transportation variable. These variables are the cost of transporting a marginal unit of a commodity either into or out of a region. For example, in explaining the location of the steel industry, explanatory variables include the marginal cost of shipping a unit of steel out of each region and the marginal cost of shipping a unit of iron ore and other inputs into each region. These are derived by determining the cost of shipping a unit of goods between each pair of regions by rail and truck for each of several weight classes. The least-cost method of shipping goods in each weight class for each commodity is determined and these costs are used in a linear programming transportation algorithm in order to produce the transportation costs.

The model starts with a set of national input-output forecasts which serve as control totals for the regional forecasts. The model requires at least two years of data, although data for additional years would be useful. The general steps of model operation are as follows:

1. Estimate demand and supply at each location for the base year (most recent year for which data are available) and the year prior to the base year. The demand for intermediate goods is estimated by applying input-output coefficients to the industry output of each region and the final demand categories are estimated directly. Final demand is estimated for twelve categories of personal consumption expenditures, gross private equipment purchases by 69 purchasing sectors, private and public construction of 28 types, federal government purchases by 7 functional groupings excluding construction, state and local government purchases excluding construction, gross exports and Federal defense expenditures. Total supply by industry is the sum of domestic output and imports, with both measured in dollars.

2. Estimate transportation costs of shipping a unit bundle of the output between each region. Transportation costs are estimated for both rail and truck shipments and are composed of both terminal and line-haul costs. These costs are estimated for different weight classes for each mode of shipment.

3. Apply a linear programming transportation model to obtain the cost of getting an additional unit of an industry's output to each region and the marginal cost of shipping an additional unit of output from each region. The linear programming model is solved for both the base year period and the year prior to the base year.

4. Using the cost for the year prior to the base period produced in step 3 and other relevant marginal costs, estimate parameters in the industry location equations. The other relevant marginal costs include annual wage rates, value of land, output in the previous period, equipment investment which serves as a proxy for capital stock, representations of major buying sectors in the regions that bought goods from the industry in question, and output of major supplying sectors in the region that sold goods to the industry in question. For the non-commodity industries (Services and Construction),

the change in output is explained by the changes in the sizes of the markets served.

5. Enter the base year's marginal costs and values of other explanatory variables into the industry location equations and make regional forecasts of changes in industry output.

6. Forecast regional employment and payrolls using the output forecasts.

7. Adjust each region's total employment and payrolls for commuting in order to convert the figures from an establishment to a residence basis.

8. Forecast regional population using the population migration equations and birth and death rates for each region.

9. Forecast regional labor force by applying labor force participation rates to the population forecasts.

10. Add to payrolls estimates of other components of personal income using the population and unemployment forecasts.

11. Forecast consumption expenditures using consumption functions that relate type of consumption with income.

12. Forecast capital expenditures using the output forecasts.

13. Update exports, imports, government expenditures by assuming that the regional distributions are exogenous.

14. Forecast intermediate demand to complete the forecast of demand or each region, recompute the marginal costs from the linear programming problem, and go back to step five using the forecasts as data and repeat the steps for next year's forecasts.

The model is based on the assumption that business firms are motivated by the desire to increase profits. They seek locations which will improve profits, for example, areas with low costs and/or high demands. A firm located in an area near its major buyers and also near its major suppliers would have an advantage over firms in the same industry located elsewhere. At any given time, firms are not located optimally, but they will always be able to move to better locations. This process is slowed by the fact that once a firm has located, then the plant and equipment are fixed at the location and the firm would hesitate to relocate.

Furthermore, the location of industry influences the location of final demand. A firm makes income payments and workers spend this money on consumption items. Therefore, if a new industry were to locate in an area, the consumption expenditures and other components of final demand would most likely increase in relation to this new industry. Thus, final components should not be determined exogenously, but endogenously, as is done in the model.

At the present time, no projections are available from the Harris model. The model is currently in the process of being verified, using 1970 data, (the original data base was developed for 1965 and 1966). Once the model is verified using the 1970 data, it is planned to employ it to make projections for 1985. These projections will be developed with the framework of national projections using an input-output model.

The regions referred to in the Harris model are the 3,112 county or county type areas within the United States. These county projections can, of course, be aggregated into a variety of regions--standard metropolitan statistical areas, states, water resource regions or air quality control regions.

The forecasts provided by the model include output, employment and earnings by industry sector, unemployment, personal income, consumption, investment, government expenditures, and population by age, race, and sex. Output is given in dollar terms. Employment projections are based on establishment data provided in County Business Patterns, and are adjusted to national totals provided in the Employment and Earnings series published by the U. S. Department of Labor. Personal income is consistent with the official estimates provided by the Bureau of Economic Analysis of the U. S. Department of Commerce. Population projections are provided for four age groups--0-14, 15-34, 35-64, and 65 and older--two race groups--white and non-white--and two sex groups--male and female. Adjustments are made within the model to correct for differences in the bases for data collection, some of which are collected on the basis of place of residence and some of which are collected on the basis of place of work. At various stages in the projection methodology, matrices are adjusted in two directions so that county totals conform to separately developed industrial, national, or state control totals for various measures of economic activity or sizes of population subgroups.

There are 99 industry sectors contained in the model. The sectors correspond closely to the Office of Business Economics (OBE) input-output sectors. In some case, these sectors are combinations of four digit SIC industries; however, the majority of the sectors are for two and three digit SIC industries.

The data requirements for this projection model are enormous. The presently available data base has been developed for 1965 and 1966 from a variety of sources. County payroll and employment data are based on reports contained in County Business Patterns. Estimates of output by county are based on a variety of sources. In particular output/ payroll ratios for states were obtained from the Annual Survey of Manufactures, 1965 and 1966, and multiplied by county payroll figures from County Business Patterns to get a first approximation to county output by industry sector. These figures were then adjusted proportionately to come to the national totals. Indicative of the resources required to develop the data base, even for a single year, is the statement by Dr. Harris that efforts were begun to update the data base for 1967, but were not completed due to lack of funds.

2.3 Operating Procedures

As stated above, plans currently exist to verify the model using 1970 county employment data. Once this verification has been completed, the model will be used to provide projections for the year 1985, working within the framework of a current effort at the University of Maryland to provide national projections for that year. No estimate was obtained of the resources required to develop these projections. However, a thoughtful examination of the magnitude of the relationships involved and the size of the data base indicate that substantial effort will be required to develop any series of projections.

The model can be used in the sensitivity analysis mode by substituting various national control totals and altering values of selected exogenous variables. In fact, it is anticipated by the model developers that it will be used in an impact anlaysis role. An example cited by them is to use the model to estimate the impact of alternative regional patterns of defense expenditures. However, because of the magnitude of the efforts involved in developing a series of projections, it is doubtful that the Harris model could be effectively and efficiently used by the EPA for the type of sensitivity analyses which appear to be relevant to their problems.

2.4 Evaluation for EPA's Use

The Harris model has several advantages when considered for EPA's use to project air emissions. First, it is based on a more satisfying theoretical foundation than some of the other types of regional projections models, e.g., those relying on a relatively unsophisticated form of shift-share analysis. The model attempts to explain the location of industry under the assumption that over time industries will change their output patterns in a desire to maximize profits. Thus, the basic model explains industrial location as an inter-regional, multi-industry disequilibrium adjustment process rather than by a partial equilibrium otpimization process.

Second, the model uses the county as a geographic data base. Thus, the output can be aggregated to any combination of counties desired--states, standard metropolitan statistical areas, or air quality control regions. Third, the model includes a fair degree of industrial detail. Although the industries contained in the model are not sufficiently detailed for air emissions projection purposes, nevertheless there is some detail at less than the two-digit SIC level. Fourth, the model does include a consistent set of projections of both population and economic activity. This consistency is necessary in order to produce a consistent set of projections of air emissions from both stationary and mobile sources.

There are also several disadvantages to use of the Harris model for projecting air emissions. Perhaps the primary disadvantage from a practical standpoint is the cost that would be required to maintain and update the requisite data base for using the model. The data base presently in existence is based on only two years of data, 1965 and 1966. It would be most desirable to provide additional observations in time with which more reliable estimates of the various relationships in the model. However, the estimation of an additional year's data base is an expensive undertaking, has not yet been accomplished, and there is no assurance that adequate financial support would be available for this undertaking in the future.

Second, although estimates of both supply and demand are available in the data base on a county basis, many of them are based on the application of fixed coefficients for larger geographic areas or categories of industrial classification. Thus, it is appropriate to question the reliability of these estimates for the smaller geographic areas. Third, a most important component of the entire projection model is the procedure for estimating the inter-county transportation costs for both raw materials and finished goods. From the documentation of the model, it appears that these transportation costs are based on an analysis of the current rates and practices of common carriers. To the extent that relative transportation costs among the various modes of transportation will vary in the future, the transportation costs developed by the linear program will give a misleading projection of the marginal costs of the expansion of industry output in each of the counties.

Finally, a procedure for comparing and evaluating the results of the Harris model with projections provided by other models and methodologies reviewed during this project does not exist. When questioned on this point, Dr. Harris was vague as to how he intended to compare his model's estimates of employment and output for 1970 with the ex-post figures for 1970. Thus, no objective criterion exists by which to ascertain if the additional resources required to provide the data base and develop projections on a county basis have been efficiently employed.

In summary, although the Harris model provides more geographic and industrial detail than any of the others reviewed, it has not been developed to a degree adequate to recommend it for EPA's use in projecting air emissions. It is necessary to examine the results of the model and desirable to have an expanded data base underlying the projections in order to make a thorough and objective evaluation of the model. Neither is available at present and hence the model is not recommended for use by the OAP.

3.0 THE MULTIREGIONAL INPUT-OUTPUT MODEL

3.1 General Characteristics

The multiregional input-output model (MRIO) provides a description of regional (state or multistate units) economic interrelationships and can be used to forecast regional economic activity based on exogenous projections of regional final demand.

The model and the projections of regional final demand for 1980 were developed primarily by individuals at Harvard University and Jack Faucett Associates. The report was sponsored by the Economic Development Administration of the U. S. Department of Commerce and also by the U. S. Departments of Transportation, Defense and Interior; and the Office of Emergency Preparedness of the Executive Office of the President.

The model is on computer tape and is expected to be released to the public during the summer of 1972.[3/]

3.2 Detailed Characteristics

The MRIO model is similar to other input-output models in its basic dimensions. It differs, however, in that it consists of interrelated input-output tables for 44 state or multistate regions.

Input-output is a method for taking into account the interdependence among the industries or sectors of an economy. The method of presenting this interdependence is by arraying the industries in an economy in matrix. When in a row the industry is a producing industry with the entries in the matrix across the row showing the industry's distribution of sales. When in a column the industry is a purchasing industry with the entries in the matrix down the column showing the industry's distribution of purchases.

In addition to the interindustry sales and purchases the input-output table also has a set of final demand columns (consumer purchases, business investment expenditures, government expenditures, and net purchases by foreigners) and a value added row (employee compensation, profits, depreciation, and indirect business taxes).

[3/] The primary documentation of the model is contained in Polenske (1970). This document contains numerous references to the various data sources and working documents that were generated as the model was developed.

Turning to a mathematical representation of an input-output model, the total output of any industry can be represented by the following equation:

$$\sum_{j=i}^{n} x_{ij} = c_i + i_i + g_i + t_i + x_i \quad (i=1,\ldots,n), \qquad (2)$$

where

x_{ij} = amount of output industry i sells to industry j,
c_i = personal consumption expenditures for the output of industry i,
i_i = private investment expenditures, including inventory changes of industry i,
g_i = government purchases of the output of industry i,
t_i = net exports of industry i,
x_i = total output of industry i.

Although input-output tables are initially developed with transactions estimates of interindustry sales and final demand purchases, the table's usefulness is greatly increased when the transactions are converted into a system of technical coefficients of production. The technical or input coefficient is the ratio of input to output and can be written as follows:

$$a_{ij} = \frac{x_{ij}}{x_j} \qquad (3)$$

where

a_{ij} = technical coefficient,
x_{ij} = amount of output of industry i purchased by industry j,
x_j = total input of industry j.

The complete set of technical coefficients arranged in matrix form show the structure of production of the economy.

Substituting the value of x_{ij} from equation (3) into equation (2) yields

$$x_i = \sum_{j=1}^{n} a_{ij}x_j + (c_i + i_i + g_i + t_i), \qquad (4)$$

In matrix notation this can be expressed as:

$$X = AX + F$$

where

F = the final demand vector c + i + g + t.

This is equivalent to:

$$X - AX = F$$

or

$$(I-A)X = F$$

where

I = the identity matrix.

Solving for X, total output, yields

$$X = (I-A)^{-1}F \qquad (5)$$

or, rewriting equation (5):

$$\begin{aligned} x_1 &= r_{11}f_1 + r_{12}f_2 + \ldots + r_{1n}f_n \\ x_2 &= r_{21}f_1 + r_{22}f_2 + \ldots + r_{2n}f_n \\ &\vdots \\ x_n &= r_{n1}f_1 + r_{n2}f_2 + \ldots + r_{nn}f_n . \end{aligned}$$

The r_{ij} are the total requirements, direct and indirect, of industry i necessary for industry j to deliver a dollar's worth of output to final demand. They differ from the a_{ij} in that they include the indirect requirements as well as the direct requirements shown in the a_{ij}. The difference in perspective can be illustrated by taking an example from the 1963 national input-output table. The technical coefficient (a_{ij}) of the motor vehicle industry for steel is 0.0863. That is, each dollar of output of motor vehicles requires 8.6 cents of direct steel purchases.

However, to build a motor vehicle requires other inputs which, in turn, require steel as an input. The technical coefficient for the rubber and miscellaneous plastics products used by the motor vehicle industry is, for example, 0.0223, but to produce rubber requires a direct input of steel of 0.0051. The total requirements of the motor vehicle industry for steel (r_{ij}) which include all the indirect steel requirements of the type cited above as well as the direct requirements is 0.2121.

The MRIO expands on the national model by identifying for every industry in a region the industry by region from which it purchases its inputs and the industry by region to which it sells its outputs.

In developing the MRIO three basic sets of data were required interindustry flows, final demands and interregional trade flows.

1. Interindustry flows. Detailed regional input requirements were assembled for the agricultural, mining and construction sectors. These estimates of requirements were based on secondary data sources. For manufacturing and services a detailed product-mix approach was used to determine state-by-state input requirements since locational factors were judged as less likely to cause significant state-to-state variations than for agricultural, mining, and construction.

   The interindustry flows are, as discussed above, converted to a system of technical coefficients. While these coefficients can be updated and even projected to reflect future price, technology and industry mix patterns, such a task is quite complex. Therefore, the most common current practice is to use the fixed coefficients for the historical period as a reasonable approximation of the future patterns.

2. Final demand. Estimates of final demand were developed for each region for 1947, 1958, and 1963. Projections of final demand were made for 1970 and 1980. Final demand consists of: personal consumption expenditures, gross private domestic investment; net inventory change; federal government purchases of goods and services; state and local government purchases of goods and services; and net foreign exports.

Changes in final demand patterns are easily handled in the input-output model. These changes can be projected for a future time period and then used to solve for the industry output necessary to meet the projected demand level and patterns.

3. Interregional trade flows. Flows were estimated from origin-destination data on commodity movement, values of total output by state, imports by port of entry, and the demand for goods by state. The flows were first estimated in physical quantities and subsequently converted to value terms. The basic geographic area for which the model and projections have been developed is for the 50 states plus the District of Columbia. However, since detailed interregional trade flows could be obtained only for 44 regions the complete model has 5 multistate regions. The model has 78 industries.

Projecting trade flows is a very complex task since, of the three areas discussed here, it has received the least analysis by economists. For that reason we expect that assumptions regarding fixed inflow coefficients will be retained by most of the early users of the MRIO model.

3.3 Operating Procedures

The model has been used by the staff of Harvard University to make industry output projections for the 44 regions for 1980. These 1980 projections are based on exogenous projections of final demand, and were developed under the assumptions of fixed technical coefficients and regional trading patterns.

The model can be used by others to provide projections for other years. However, as the projection period increases the assumption of the fixed coefficients and inflows becomes more open to question.

3.4 Evaluation for EPA's Use

The MRIO model can provide a consistent set of interrelated regional projections. It can be explicitly adjusted to account for new industries, technologies or trading relationships. It is, therefore, particulary useful for determining the economic impacts of alternative policies. For example, if an industry increases its output there will be an increase in the outputs of the industries supplying inputs to it. The model provides a convenient means for accounting for these interrelationships and for calculating these increases and, given output-emission relationships, could estimate changes in emissions levels.

There are, however, several disadvantages to the use of the MRIO model for projecting regional economic activity and the associated air emissions. First, as presently developed and implemented, the regions in the model are states, or in some cases multistate units. Any projections for these regions would have to be further disaggregated to be of use to the OAP, an effort which would require a significant amount of resources. Also, it is questionable whether an input-output approach could be effectively implemented at a sub-state level because of problems of data availability (see the discussion of the Harris model in Section 2.0 of this appendix). Therefore, much of the value of the model would be lost.

Perhaps more important, the MRIO model gives projections of only one economic measure - the output of the various industry groups measured in dollar terms. The problem of developing a measure of physical output remains, one which is not unique to the MRIO model, as discussed in other sections of this memorandum. Although the MRIO model may possibly provide a useful framework for projecting air emissions from point sources, other measures (population, income) that are necessary to project air emissions from mobile and area sources are not available from the model. Thus additional model development efforts would be necessary to provide consistent employment, output, population and income projections from the MRIO model.

In addition, at the present time there are no plans to provide projections for any other time period except that already developed--1980. State projections using the input-output model for other years would have to be calculated during further development of the overall air emissions projection framework, a task that would require a significant amount of resources. But the projections already developed are based on the 1963 technology matrix. If projections beyond 1980 were made this assumption of fixed coefficients becomes even more questionable. Finally, there are no known plans at present for the government to continue this research or to update the model.

In summary, although it is felt that input-output analysis does provide a valuable tool for regional analysis, for the reasons cited above, it is not recommended that the MRIO model be used to provide an overall framework for air emission projections. It is possible, however, that the MRIO model could be useful in other EPA applications and for these reasons its characteristics should not be completely overlooked.

4.0 THE NPA PROJECTIONS

4.1 General Characteristics

For more than two decades the National Planning Association (NPA) has been a pioneer in economic projections. In addition to short-term forecasts for the overall economy, NPA makes detailed five and ten year projections of the national economy and the economies of regions, states and metropolitan areas.

The National Economic Projections provide five and ten year projections of gross national product; industrial sales (shipments); output and employment; investment, capital stock and productivity; consumption; personal income and income distribution; and government spending and revenues. Accompanying the projections are historical data for key series. The National Economic Projections are published annually in a volume of some 300 pages ot text and statistical tables.[4/] To facilitate its use, statistical material is similar in definitions, format and sequence to the national income and product account tables of the U. S. Department of Commerce.

The Regional Economic Projections forecast population, employment, personal income, and consumption for five and ten years for eight multistate regions, all states, and 224 metropolitan areas.[5/] Considerable emphasis is placed on estimating fugure patterns of interstate migration and industrial location. The Regional Economic Projections are published annually in volumes containing several hundred pages of text and tables.[6/]

The projections are developed by the National Planning Association in its Center for Economic Projections. The work of the Center is assisted by a Research Advisory Committee consisting of experts from business, labor and government.

[4/] The latest series of NPA national projections are available in Al-Samarrie and Scott (1971b).

[5/] The most recently published and metropolitan area and state projections are available in National Planning Association, (1970a and 1970b), respectively.

[6/] The "metropolitan areas" as used by the NPA are identical with the "Standard Metropolitan Statistical Areas" as specified by the Office of Management and Budget.

Projections of relevant measures of economic activity for the Nation are provided by a computer-implemented econometric model of the U. S. economy.[7] Projections of economic activity in states and metropolitan areas are initially developed by extrapolating recent trends in the relative shares of activity in these areas. These trends, however, are modified by such considerations as relative stages of industrial development in each state, extent of urbanization, physical, natural and labor resources available, and trends in new technological requirements, as well as consideration of feedbacks on employment on income growth, population shifts, and labor force changes. These modifications were introduced partly because the available data permit judgments of a very loose sort, and partly because the state and the metropolitan areas are usually not economic entities providing appropriate analytical units. Thus, the NPA projections have been developed by a combination of man and machine techniques.

4.2 Detailed Characteristics

The NPA national model contains functions for generating projections of 99 endogenous variables, and requires the stipulation of numerical values for 34 variables that are exogenous to the model. In forming judgments concerning the merits of the current series of NPA Projections, the reader should review the key assumptions behind the exogenous stipulations. These assumptions are: the population projections used are those calculated by the Bureau of the Census; these projections employ an average of the so-called "C" and "D" series fertility rate assumptions that, respectively, women will bear 2.78 and 2.45 children during their lifetimes.

The armed forces are assumed to decline gradually to 2.6 million, remaining at that level for the rest of the 1970 decade; and state and local government employment is assumed to increase by approximately 36 percent, and that federal government employment is expected to increase by approximately 17 percent between 1971 and 1980.

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[7] /Documentation of this model is available in Al-Samarrie and Scott (1971).

Other assumptions are that productivity is expected to grow at about three percent per year over the coming decade, a pace not significantly different from that experience during the 1960's. The real output per man hour rate for the first half of the 1970's is expected to be 3.0 percent, decreasing slightly to 2.8 percent during the last half of the decade. Each of these assumptions is reasonably consistent with those used by BEA and the Interagency Growth Project in developing their respective 1980 projections of national economic activity.

The NPA projections are developed in two stages. First, the national projections are determined and then these are disaggregated to the regional projections. The equations used in the national model are divided into four groups:

1. Those explaining the calculations of gross national product from the supply side;
2. Those explaining the expenditure components of gross national product;
3. Price deflators;
4. Income components.

The supply equations for computing GNP arise from the employment of the projected labor force and capital stocks at the projected rate of unemployment and capacity utilization. Alternatively, it is the GNP required if the stipulated unemployment rate is to be achieved. To compute the expenditure or demand side of GNP, producers' durable equipment and private non-residential structures investment data, state and local government purchases, personal consumption expenditures, and imports are estimated through the use of behavioral equations. Other sectors of final demand (residential construction, inventory changes, exports, and Federal purchases) are considered as exogenous variables outside the model.

The overall price deflator is exogenously determined through equations to estimate most sectoral price deflators. In considering GNP as the sum of disposable incomes, the income side of GNP is calculated as the sum of disposable incomes - personal - business and government. The model employs behavioral equations, identities and stipulations to project the items incorporated in these aggregates.

Turning to the state projections, employment is first divided into two sectors - commodity-producing industries, (agriculture, forestry and fishery; mining; and manufacturing) and non-commodity industries, (the other broad industrial 1-digit groups). A modified version of the differential shift analysis is used to disaggregate the projected national employment in each commodity-producing industry among the states.[8/] As expected, annual variations in the differential effect for a specific industry within a state are erratic. However, over longer periods of time the differential effect has displayed a greater consistency, which is used along with a strong dose of judgment for trend modification, to project the values of the industry differential effects in each state. The fact that the sum of the differential effects for all states nets out to zero prevents the results from exceeding the national totals. Employment in non-commodity industries is projected as a function of commodity-producing industry employment in each state. In this procedure, trends and the ratio of commodity to non-commodity employment in each state are compared with those in the nation and projected values are developed.

Members of the labor force by age and sex are projected for each state and these cohorts are combined to yield the total state labor force for the projection year. The age-sex cohorts are projected by comparing trends in labor force participation rates for the state with the national rates. Projected labor force participation rates for the nation are obtained from the Bureau of Labor Statistics of the U. S. Department of Labor.

State personal income projections are made on the basis of per capita relatives to the nation. That is, past trends in state per capita personal income relative to national per capita personal income are extrapolated to the projected year. The projected state relatives are multiplied by the projected level of national per capita personal income to yield projected state per capita personal income figures.

[8/] Details of this procedure are provided in National Planning Association (1965, pp. 68-71).

Projected values of disposable personal income, that is income after deductions for personal tax and non-tax payments, are developed by extrapolating past trends in the ratio of implicit state personal tax rates to implicit national tax rates.

Personal consumption expenditures are projected by first developing national consumption functions for each consumption item using a least squares equation which relates the percent share of disposable personal income spent on a particular consumption item as dependent variable to per capita disposable personal income as independent variable. Personal consumption totals for each state are developed from the national totals by modifying the national figures to reflect regional differentials in consumption patterns for a particular consumption item.

The metropolitan area projections are developed by the same general procedures as those for the states. That is, metropolitan area economic and demographic activity is related to economic activity in the relevant state and other analytically relevant control areas.

National, state and regional projections are prepared by the NPA on a regular basis. At the present time national economic projections are available for 1980. State economic and demographic projections are available for 1975 and 1980; Metropolitan Area projections are also available for 1975 and 1980.

The basic geographic areas for which the sub-national projections have been developed are the 50 states and the District of Columbia. In addition, the state projections have been aggregated into eight major regions: New England, Middle Atlantic, Great Lakes, Southeast, Plains, Southwest, Mountains, and Far West. Projections are also available for 224 metropolitan areas.

At the national level the NPA economic projections include the following variables: gross national product by 17 major components in current and constant prices, personal income by nine income sources, personal consumption expenditures by 83 product categories, distribution of consumer units by eight income classes, gross sales by 86 industry groups, gross output per worker for 64 industries, gross and net capital stocks by industry sector for 20 types of equipment and 10 types of structures, purchases of non-residential structures and producers durable equipment by type, government expenditures by 45 program categories by level of government, government revenues, merchandise exports and imports by 86 industry groups, and population and labor force by age, sex and color.

At the regional level NPA projections include the following variables: population by region and state, employment in 30 industry sectors by region and state, total and per capita personal income by region and state, total and per capita consumption expenditures by region and state for 80 consumer product items. Metropolitan area projections include population, population density, employment, and total and per capita personal income.

The employment series used in the projections is conceptually equivalent to a count of the number of full - part-time jobs filled, including both wage and salary workers and self-employed. Comparable national aggregates were derived from the industry employment series reported in the Survey of Current Business by the Bureau of Economic Analysis. Population data represent mid-year (July 1) resident population including both civilian population and Armed Forces stationed in a given state. In the regional series, personal income, personal consumption expenditures, personal taxes, and personal saving are expressed in constant 1968 dollars. In the national projections, GNP and national income figures are projected in both 1958 and current dollars.

Employment projections are available for each state at the 2-digit level of detail for manufacturing and at the 1-digit level for other industries. Employment projections for the metropolitan areas are provided only at the 1-digit level of detail. Exceptions are that manufacturing is broken out into durable and non-durable good industries, trade is divided into wholesale and retail components and civilian government employment is provided separately for the Federal and state and local sectors.

The data base for the NPA national projections series is that of the national income and product accounts. State employment data are based on statistics from Employment and Earnings reports supplemented by a variety of sources to develop estimates in various sectors not covered fully in these reports. The state personal income series is that provided by the Bureau of Economic Analysis of the U. S. Department of Commerce. Basic data for the personal consumption projections are developed from the 1960-1961 Survey of Consumer Expenditures, prepared by the Bureau of Labor Statistics and Market Profiles of Consumer Products, issued by the National Industrial Conference Board in 1966.

4.3 Operating Procedures

The National Planning Association has been engaged in a regular program of providing national and regional economic and demographic projections for a number of years. At the present time, both the national and regional and state projections are revised on an annual basis.

As it is presently operating, the econometric model used by NPA to provide national economic projections cannot easily incorporate alternative assumptions. However, efforts are under way to modify the model so that the effects of alternative assumptions about the course of the future can be reflected in different projection series. For sensitivity analyses at the regional level, as with other models it may be more appropriate to take the relatively aggregated national output as fixed and perform the industrial and geographic sensitivity calculations within this framework.

4.4 Evaluation for EPA's Use

The NPA projections provide a set of consistent national and regional projections of population, personal income, employment and personal consumption expenditures. National projections of gross output per worker for 64 industries, a measure which may be useful in developing indices of physical output, are also provided. The National Planning Association is committed to continuing the projection program, as national and regional projections have been updated on an annual basis in the past and are developed as part of an on-going program at NPA.

The primary disadvantage of the NPA projections for EPA's use is that the appropriate measures are not provided in the necessary detail to project air emissions. In order to project these emissions, some measure of output by industrial sector is required, whereas the NPA projections furnish only employment projections. In addition, particularly for the metropolitan areas employment projections are provided for industries that are too highly aggregated to be of practical use in projecting air emissions. Finally, at the present time projections are available only for 1980. This time-frame may not be adequate for the EPA's use.

In summary, althouth the NPA projections are developed on an adequate geographic basis for use in projecting air emissions and are part of a continuing program, they are not provided in sufficient industrial detail at the substate level and are therefore not recommended for further consideration by the OAP.

5.0 THE OCD PROJECTIONS

5.1 General Characteristics

The objectives of the program under which the economic projections have been produced were to develop a series of models for evaluating the vulnerability of national systems in the event of a nuclear attack. The entire series includes separate models for projecting surviving population and industrial capacity from the attack, post-attack demand, and the degree to which sufficient capacity exists to meet the post-attack demands for consumption and recovery. The discussion in this memorandum will be limited to the projections of economic activity.

The entire series of models were developed by a variety of contractors under the sponsorship of the Ofice of Civil Defense. The projections of economic activity were developed by the Institute for Defense Analyses (IDA). The data base on which the projections are based was developed primarily by Jack Faucette Associates.

The projections provided by this system are developed from a series of computer models. Once the models are placed in operation no manual intervention is made.

5.2 Detailed Characteristics

A series of assumptions are implicitly contained in these projection methodologies. Of particular importance for the economic projections is the fact that national projections of economic activity are those provided by the U. S. Department of Labor as part of the Interagency Growth Project. These projections have been published as a part of an analyses and examination of growth prospects of the U. S. economy to the year 1980. Population projections have been provided by the U. S. Bureau of the Census.

Population projections for 1975 are provided for each of the approximately 3,000 counties in the United States by the Bureau of the Census. From the available documentation, it is difficult to determine what assumptions have been input to those projections. In particular, it is difficult to determine if they are in any way consistent with any independent projections of employment growth by county.

The other projections contained in the data base are those for value added and number of firms. Each of these series is projected as a function of the population totals in the counties for both 1975 and 1960 (Institute for Defense Analyses, 1971, pp. III-4 - III-7). The projected values for each county are then adjusted to the national control totals developed from the Department of Labor projections discussed above.

Projections are currently available for the year 1975. The overall project at IDA contains projections of other economic variables, for example personal consumption expenditures, for alternative years. However, the value added and number of establishment projections are currently available only for 1975.

The basic geographic areas for which the economic projections are available are the approximately 3,000 counties in the United States. Projections of final demand, personal consumption expenditures, and other aggregates are only available at the national level.

County projections include population, value added, and number of firms. Value added is projected in 1958 dollars for each of the sectors of the national input-output table. The number of firms is projected for four size classes, only for manufacturing industries: 1-249 employees, 250-499 employees, 500-999 employees, and 1,000 employees and over.

The basic data on which the projections are based and the projections themselves are available on tape at the Institute for Defense Analyses.[9] In addition, a series of summary indicators of the concentration and dispersion of industrial activity by county have been prepared for each of the sectors. These indicators are available both in terms of single numerical values and in terms of empirically fitted curves to the geographic distribution of industrial output.

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[9] The value added data base from which the projections are derived was developed by Jack Faucette Associates (1968) and are based on the results of the 1963 Census of Manufactures.

5.3 Operating Procedures

At the present time, there is no assurance that the projections for 1975 will be updated. However, the Office of Civil Defense, subject to the availability of funds, plans to incorporate the result of the 1970 Census of Population into the population data base. These results would then presumably be used to update the projections of value added and number of establishments for some time period beyond 1975.

In their present form the data series discussed above does not appear to be very amenable for sensitivity analyses. As with other modes, it seems to be more appropriate to take the relatively aggregated output of these projections as fixed and perform the industrial and geographic sensitivity calculations within this framework.

5.4 Evaluation for EPA's Use

The projections surveyed above are not appropriate for use of EPA in projecting air emissions. First, at the present time they exist for only 1975. Although they are available at the county level of detail, the approach to their development is not very rigorous. More acceptable projections are available from other organizations, although they are not necessarily available at the county level of detail. It appears that the most appropriate use of the data developed and used by the Office of Civil Defense and the Institute for Defense Analyses will be in developing the outline of techniques for projecting output at the county level. The summary statistics of industrial concentration and dispersion and the empirically fitted curves of the geographic distribution of industrial output should provide useful inputs to this portion of the development of the overall national-regional model for projecting economic activity.

6.0 THE BLS PROJECTIONS

The final series of projections reviewed in this memorandum are those prepared by the Bureau of Labor Statistics as part of a large study of future patterns of growth in the U. S. economy.[10] These projections are provided at the national level only and therefore are not appropriate to serve as detailed inputs to a regional air emission projection methodology. Accordingly, the projection methodology is not reviewed in as great a detail as those of the other sections of this memorandum. However, highlights of the projection methodology are briefly reviewed, in particular to summarize the fairly detailed set of national industrial projections that have been developed for 1980 which may provide useful control totals in developing more detailed regional projections for EPA's regional air emission forecasting efforts. In addition, a variety of supplementary data have been developed in association with the overall effort. Certain of these data may also provide useful inputs to the EPA air emission projection model.

The BLS estimates of 1980 demand, output and employment are not forecasts but projections of what the economy might be like under a given set of assumptions. Projections for four alternative 1980 models have been developed. These four are grouped into two sets: one set termed the basic model and the other the high durable goods model. The basic models represent what is believed to be the more likely projections for 1980 and reflect the long-term shift toward the service producing and away from the goods producing sectors of the nation's economy. As the description implies, the high durable goods set emphasizes expenditures on durable goods. Each of the sets has two models with identical characteristics throughout except for the unemployment rate which is varied: one of the models in each set has a three percent unemployment rate and the other has a four percent rate.

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[10] These projections and a discussion of the procedures employed in their development are contained in U. S. Department of Labor (1970).

The 1980 projections are made in a series of distinct but closely inter-related steps. First, potential GNP is developed based on a projection of the labor force, assumptions regarding the rate of unemployment and the level of the Armed Forces, and projections of trends in average hours and output per man hour. Given the potential GNP, projections are developed of the composition of GNP among demand components, government, consumption, business investment and foreign demand. Once the composition of GNP is determined, the detailed distribution of each of these final demand components is projected.

In order to translate projections of industry demand into industry output requirements, input-output relationships which have been projected to 1980 are used. After the calculation of industry output growth rates are completed, the final step is to derive the projected level of employment by industry, by using projections of changes in output per man hour by industry. Finally, demand generated employment is reconciled with that resulting from the population and labor force projections.

In the BLS projections, all productive activities are classified into 87 industries. In particular, it should be noted that industrial detail is available for some sectors for combinations of three- and four-digit SIC industries.

Although no firm schedules have been developed, it is assumed that updated national projections using this approach will be periodically prepared in the future. Thus, a series of national projections will be available in the future to provide useful inputs into the EPA air emissions projections methodology.

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APPENDIX B

IRON AND STEEL INDUSTRY

1.0 INTRODUCTION

The iron and steel industry (SIC 3312, Blast Furnaces and Steel Mills) is a substantial emitter of particulates from the sintering operation, the coking ovens, the steel making furnaces, and the scarfing operations. There are good data on the capacity of the industry, the production processes, and the controls. The major tasks in projecting emissions on a regional basis are predicting the future output of steel and allocating this on a regional basis.

2.0 PROJECTION CHARACTERISTICS

2.1 Demand and Supply

Output in the steel industry is dependent upon the demand for steel and imports. The demand for steel products is probably easier to project than the supply from domestic sources. Demand is a function of population, income, and the price and competitive advantages of the product compared with other materials such as aluminum, glass, wood, and plastics. The domestic supply is dependent upon the demand for the product, prevailing prices, the effect of import quotas, and recycling.

2.1.1 Demand

A very detailed study of the demand for steel mill products has been published by the Bureau of Mines.[1] This study projects the demand for the various types of steel mill products. The demand is dependent upon such factors as population, income, the prices of steel products and competing materials, the composition of total demand in 1980, and the growth of industrial uses of steel. Although this study can be used as the basis for making projections of the demand for steel mill products, special care must be taken to insure that the projections are consistent with the projection of demand for aluminum and other materials that will be made in this study.

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[1] Mo, William Y. and King-Lee Wang. A Quantitative Economic Analysis and Long Run Projections of the Demand for Steel Mill Products. Bureau of Mines Information Circular 8451. Washington, D. C.: Government Printing Office 1970.

2.1.2 Supply

The most critical factor in projecting supply, once demand has been determined, is imports. Prices for imported steel will have to be compared with the expected prices for domestic steel in order to determine the percentage of steel demand that will be supplied by imports. Because all steel mills do not produce the same mix of products, the composition of imports will have an influence on the location of domestic steel production. The competitive position of each of the major steel mill products will have to be examined in some detail.

Another important influence on the supply of steel mill products is recycling. Recycled steel is a good substitute for virgin steel in most uses. Any increases in the amount of steel recycled will result in decreases in the amount of primary steel produced, assuming demand is constant. The current effort to recycle all types of scrap materials along with legislative changes to make secondary materials more competitive will undoubtedly have a significant influence on the amount of steel recycled. Handicaps to the use of recycled steel such as discriminatory freight rates, depletion allowances for virgin materials, and purchase specifications will probably be removed.

Current trends in production capacity for various types of steel mill products will have to be examined as well as industry projections of this capacity. Growth in particular types of capacity is probably a good indicator that the domestic production of these steel mill products will continue to be healthy.

2.2 Location

2.2.1 Data

Data are available on the current location of steel mills, on the mills that are growing and contracting, on the processes used, and on the control devices employed. Most of these data have already been computerized, although data on coking ovens and their emissions still have to be added.

2.2.2 Regional Shares of Production

Total output of the domestic steel industry needs to be allocated among existing plants and among possible new plants. The exact location of new plants cannot be known. In the case of steel mills, however, the possibility of the new mills within the next five to ten years can be learned from examination of trade sources. New mills beyond this time period can only be hypothesized on the basis of locational factors such as access to markets and raw materials. The possible sites can be included in the projection model. That is, the model can be run under the hypothesis of what will happen to emissions if a steel mill is located in this or that very likely place.

The allocation of production among existing plants is the primary locational problem in the iron and steel industry. There are data available on the production levels of the various steel mills that permit projections of output at each of these mills. Output by major product will also be necessary. Some factors that influence production of particular products at a particular steel mill are the demand, the efficiency of the production equipment, the access to markets, and the competition from imports. These various factors will have to be examined in projecting output from each steel mill.

2.3 Process

Although there are currently three types of steel making processes in use, the projection of output by process should not be a major problem. Data are currently available on production processes by plant. Furthermore, there is a very distinct trend away from open hearth furnaces.

The trend away from sintering toward pelletizing will also probably continue. Projection of this trend and its favorable effects on emissions should not present any problems.

3.0 SUMMARY

The major tasks in projecting emissions from the iron and steel industry are the projection of the demand for and the supply of steel mill products and the allocation of the domestic production among regions. Projections of the demand for steel mill products can be made readily; projections of the supply of these products will be more difficult because of imports and recycling. The allocation of domestic supplies of steel mill products on a regional basis will be a time consuming, though not particularly difficult task. Projection of trends of various steel mill products from each of the steel mills will provide a good guide to the regional allocation.

APPENDIX C

PRIMARY COPPER

1.0 INTRODUCTION

The primary copper industry, SIC 3331, consists of the smelting and refining of copper ore. Copper smelters are the largest point sources of sulfur oxide emissions. The relatively small number of smelters is well documented as to location, production, capacity, processes, and controls. The major tasks in projecting emissions from the copper industry will be to estimate the supply of copper from domestic sources and the location of these sources.

2.0 PROJECTION CHARACTERISTICS

2.1 Demand and Supply

2.1.1 Demand

The total demand for copper has been projected by the Bureau of Mines. More detailed projections may be necessary in order to insure that the projections are compatible with the projection of competing products. Copper can substitute in various uses for aluminum, steel, plastics, and to a degree, zinc. The primary competition, however, is with aluminum. Other factors that influence the demand for copper are the price of the product, the population, the income levels and the increased uses to which copper is put.

2.1.2 Supply

The supply of domestic copper is due to the demand for copper, the supply of imported copper ore and finished copper, and the amount of copper that is recycled. The total supply of copper, of course, is determined in part by the interactions of price with the demand for copper.

Imports of copper and copper ore are dependent upon the current demand for copper and the capatibility of the domestic copper industry to supply that demand. The domestic price for copper varies from the world price; it may be higher, though in recent years it has often been substantially lower. Projections of copper imports will require a detailed study of the comparative advantages of domestic and imported copper as well as the regulations and legal restirctions on copper imports. The comparative advantage of domestic producers may change due to the need to install emission control equipment. Preliminary studies indicate that these controls, while requiring large expenditures of funds, are not likely to affect the price of copper by more than a few percentage points.

Another factor that has a large influence on the supply of domestic copper is the amount of copper that is recycled. The high value per pound of copper is responsible for the large percentage of copper that is recycled. Furthermore, much of the copper is contained in items such as automobile radiators and electric power equipment that can readily be collected and recycled. New regulations and laws affecting the secondary materials market may have an effect on the amount of copper that is recycled, and therefore, on the amount of primary copper that is produced.

2.2 Location

Data are available on the location of every copper smelter and on production levels at these smelters. For projections it will be necessary to determine the allocation of future copper production among existing smelters and possible new smelters. Any new smelters likely to be constructed within the next five years or so can probably be determined from industry sources. New smelters beyond this point in time will depend upon current supply and demand relationships. The most likely location of new copper smelters can probably be determined through industry sources and Bureau of Mines data.

Current production rates at existing smelters should prove a guide to future regional shares of production. Trends in the share of production among smelters exist because certain smelters have competitive advantages over others. That is, their equipment is newer, more efficient, or they are located near more desirable inputs or closer to markets. These trends in output at each smelter can be projected based on past data and expected changes in the future.

3.0 SUMMARY

The major task in this project is to project the domestic supply of copper. The demand also has to be projected but this can be based largely on projections made by the Bureau of the Mines. The domestic supply is dependent on imports and upon recycling activities. The secondary task is to allocate production among the existing smelters and to hypothesize upon the existence of new smelters. The most likely locations for new smelters can be inserted into the projection model in order to make projections conditional upon the establishment of the new smelter. No new data are required for primary copper.

APPENDIX D

PRIMARY LEAD

1.0 INTRODUCTION

The primary lead industry, SIC 3312, consists of the smelting and refining of lead. The six lead smelters are an important source of sulfur oxides. Detailed information is available on the capacity, output, production processes, and controls of the existing lead smelters. The primary task will be to project the demands for and the supply of lead and to allocate this supply among the existing smelters.

2.0 PROJECTION CHARACTERISTICS

2.1 Demand and Supply

2.1.1 Demand

The demand for primary lead has been growing slowly due to the increasing life of automobile batteries and the recycling of almost all batteries. The other large use of lead, tetraethyl lead in gasoline, is declining and may soon disappear due to restrictions on the lead content of gasoline. The projected demand for lead will have to take these two factors into consideration as well as other uses for lead. Projections of the demands for lead have been made by the Bureau of Mines, but these will have to be examined very closely for their assumptions.

2.1.2 Supply

The domestic supply of lead depends upon demand, imports, and the secondary lead supply. Imports have shifted over time as prices change and must be examined very closely. It is likely that imports will cease if the demand for lead declines. The other important supply factor is the secondary lead market. About 94 percent of all batteries are recycled and the lead from these batteries is a perfect substitute for new primary lead. Because such a high percentage of the recycleable lead is already recycled, lead imports will probably be the major hurdle to calculating the domestic supply of lead.

2.2 Location

The location and output of all the lead smelters is known. Trends in production are also known and can be projected using past data as well as other factors that determine output. Some other factors are access to raw materials and to markets, wage rates, and efficiency of production. Using these factors, output can be allocated to each of the smelters. The critical point in allocating output is deciding whether some of these smelters will close in the future. The possibility of closures can be examined through industry sources as well as by an examination of the factors that influence the allocation of shares among smelters.

3.0 SUMMARY

The major task in this industry is to project the demand for lead. The critical assumptions have to do with the use of tetraethyl lead in gasoline. The supply of domestic primary lead also has to be projected; it will depend upon the level of imports and the percentage of lead that is recycled. The critical point in allocating domestic lead production among the primary producers is whether any of them will close during the projection period. Current data and trade journals should provide sufficient information to project emissions in this industry.

APPENDIX E

PRIMARY ZINC

1.0 INTRODUCTION

The primary zinc industry, SIC 3333, includes the smelting and refining of zinc from the ore. The fifteen zinc smelters around the country are important sources of sulfur oxide emissions. The tasks are to project the demand for zinc, the domestic supply, and the location of production. The possibility of closures also has to be considered.

2.0 PROJECTION CHARACTERISTICS

2.1 Demand and Supply

2.1.1 Demand

The demand for zinc has been projected by the Bureau of Mines. The demand is dependent upon such things as population, income, and the growth of end-uses of zinc. There is some substitution for zinc by other materials such as steel, copper, aluminum, and plastics. The primary consideration in adopting the projections of the Bureau of Mines is to ensure that they are consistent with the projections for the other primary and secondary metals.

2.1.2 Supply

The supply of zinc is dependent upon the demand and upon imports. Zinc imports are not substantial at the present time. Very little zinc is recycled because it is used primarily as an alloy in other metals and recovery is difficult. Trends in domestic zinc production and their impact on imports will have to be examined in order to determine the expected level of imports in the future.

2.2 Location

The primary problem of location will be to allocate the production of zinc among the existing zinc smelters. A secondary consideration will be to consider the possibility of closure of one or more zinc smelters. An examination of industry sources as well as the usual measures of economic performance will provide some guides to the possibility of closure.

2.3 Production Process

Although various processes are used in zinc smelting, sufficient data are available to permit projection of trends without great difficulty. There are also data on the various types of controls.

3.0 SUMMARY

The primary task in projecting emissions from the primary zinc industry is to project the demand for zinc. A secondary task is to project the domestic supply of zinc and to allocate it among existing plants. The major uncertainty will be the possible closure of one or more zinc smelters. There are no special data requirements for projecting this industry. The level of effort required for projecting this industry will probably be substantially less than for the other primary metals.

APPENDIX F

PRIMARY ALUMINUM

1.0 INTRODUCTION

The primary aluminum industry, SIC 3334, is a significant source of particulate emissions. There are presently 25 establishments located mainly in the South and West where cheap electricity is available. Aluminum production is growing rapidly compared with the other primary metals, in part because the industry is aggressively seeking out new uses. The major tasks in this industry will be to project the demand and supply of aluminum and to allocate production among existing sources. The location of possible new sources will be hypothesized.

2.0 PROJECTION CHARACTERISTICS

2.1 Demand and Supply

2.1.1 Demand

The production of aluminum has grown rapidly during the last twenty years due to increased demand for the material resulting from its substitution for other metals. For example, aluminum competes with steel in engine blocks for automobiles and with copper for radiators in automobiles. There is also severe competition between aluminum and copper for electrical transmission lines. Some of the competition is based on the superior technical characteristics of aluminum while the other is based almost purely on price. Aluminum prices have been quite stable and this has permitted the metal to capture a larger share of the market when the prices of other metals were rising.

Although projections of aluminum have been made by the Bureau of Mines using relatively unsophisticated techniques, a more detailed study is probably called for. The demand for aluminum depends upon its price and the prices of competing metals. It also depends on population, income, and the growth of the various end-products in which aluminum is used. Some of these end-products are electrical transmission lines, automobile radiators, packaging products, and various construction materials such as structural shapes and siding. There are also small amounts of aluminum exported and these exports will have to be explicitly considered.

2.1.2 Supply

The supply of aluminum from domestic sources depends upon the demand, imports, and recycling. Aluminum capacity has been keeping pace with the growth of demand. Production costs in comparison with foreign sources of aluminum could be a factor leading to an increase in imports. Imports occur when they offer a price advantage over domestic aluminum or when domestic aluminum is not able to supply total demand. In general, imports have not been a significant part of the aluminum market, but this may change due to rapidly increasing electricity prices in the United States and a concern for environmental quality. Much of the bauxite used by the aluminum industry is imported and could be smelted outside the United States.

A second factor influencing the domestic supply of aluminum is the amount of recycled aluminum available. There has always been an effort to recycle aluminum because of the high value per ton of the metal. A recent effort has concentrated on recycling aluminum beverage containers which are an important part of total output and are available for recycling as soon as the beverage is consumed. Because aluminum production has grown rapidly, the amount of aluminum being released from long-term uses is relatively small.

2.2 Location

The primary determinant of location in the aluminum smelting industry is the availability of cheap sources of electricity. Secondary considerations are access to raw materials and access to markets. The number of establishments has been increasing and is likely to do so in the future. Because raw materials and market location are not very good indicators of aluminum smelting locations, new establishments spring up in unexpected places. It may not be possible, therefore, to predict with any degree of certainty, where new aluminum smelters will occur. The more likely locations can be hypothesized and tested for their emission implications.

The major part of this task will be allocation of production among existing sources. This can be done using the knowledge of plant capacity and patterns of growth among the plants. There is a tendency to build plants with the flexibility to increase capacity and this tendency must be taken into consideration when allocating the production of aluminum among domestic sources. An examination of trade data sources and of electricity supply capacity near existing smelters should provide guidance to future production levels.

2.3 Production Process

The production processes in use are known at all but two plants. The trends in the production process are also known. It is unlikely that production processes and controls will present any great difficulties in making projections.

3.0 SUMMARY

The primary task in projecting emissions from the aluminum industry will be to project the demand for the product and the percentage of demand that will be supplied from domestic sources. The secondary task will be to allocate production among existing sources. Some attention should be given to the most likely locations for new aluminum smelters.

APPENDIX G

PETROLEUM REFINING

1.0 INTRODUCTION

Petroleum refining and the storage of crude and refined products, SIC 2091, is a source of particles, sulfur oxides, carbon monoxide, and hydrocarbons. The industry is growing and its activities are located in a large number of places throughout the nation. Emissions depend upon the process type used.

2.0 PROJECTION CHARACTERISTICS

2.1 Demand and Supply

2.1.1 Demand

The demand for petroleum products has been growing rapidly. Some of the major uses are as fuel for vehicles, electric power generation plants, and other types of combustion. The demand for petroleum can be related to the growth of the various uses of petroleum products. These in turn are related to the population and income, to the patterns of vehicle ownership, and to the production of electrical power from various types of fuel. The prices of competing fuels are also an important determinant of the demand for petroleum. Good projections of industry output already exist for the two-digit industry SIC identifier of which petroleum refining is a part.

2.1.2 Supply

The supply of petroleum products is more difficult to project than demand. The source of the crude petroleum is important. The sulfur content and other characteristics of the crude vary between domestic and foreign sources, and these characteristics affect the emissions. Present levels of domestic crude production will have to be projected in order to determine the amount of foreign crude. Recycling will not be a major problem because most petroleum is burned and thus cannot be recycled. Offshore refining of foreign crude is something that has to be considered as a possibility of the future. Another consideration will be the possible conversion of coal or other fuels into petroleum. This would have an obvious effect on the domestic supply.

2.2 Location

Petroleum refineries are located in areas of crude petroleum production, near seaports, or near population centers served by a pipeline. There will be a shrinkage of the share of refineries near domestic sources of petroleum because of increased imports. These imports generally go directly to the points of major usage. About half of all refineries are located in Texas, Louisiana, and Ohio. California, Pennsylvania, and Illinois account for another quarter of the production.

The shares of domestic production may be allocated among existing refineries on the basis of capacity, crude petroleum supplies, access to markets, and trends in production. New refineries will have to be predicted because of the growing significance of the imported crude petroleum. There will probably be new refineries along the East Coast, but the exact location can not be known with certainty. The most likely locations can be hypothesized and the model operated under these hypotheses.

2.3 Process

The major distinguishing characteristic among refineries is the presence or absence of a fluid catalytic cracker. The catalytic cracker requires a catalyst regenerator which produces carbon monoxide and other emissions. Because the emissions from refineries do vary with the particular process used, process information must be collected and projected.

3.0 SUMMARY

The most critical step in projecting emissions from petroleum refineries is to project the domestic supply of crude petroleum. Once this is done, imports can be calculated and production allocated among the various refineries. Imports are significant because they shift production away from refineries in areas of crude petroleum sources toward population centers. Another aspect that requires attention is the production process used at each refinery.

APPENDIX H

SECONDARY NONFERROUS METALS

1.0 INTRODUCTION

The secondary nonferrous metals industry, SIC 3341, is a source of particulate emissions. Emissions from any one establishment are relatively small by comparison with most other point sources, but the large number of plants makes the industry as a whole a significant emission source.

2.0 PROJECTION CHARACTERISTICS

2.1 Demand and Supply

2.1.1 Demand

The demand for most secondary nonferrous metals parallels the demand for the primary metals; however, the demand for nonferrous metals such as secondary gold, silver, platinum and various alloys is independent. Only the secondary production of copper, lead, zinc, and aluminum will be considered because emission factors for these are available.

2.1.2 Supply

The supply or output of the secondary nonferrous metal industry depends on a number of different factors. The cost of obtaining the supply of raw materials (scrap metal) together with the price that can be obtained for the finished product is an obvious determinant of output. Another factor is the foreign market for scrap metals. In many cases it is more profitable to export the scrap than to melt it and produce secondary metals that can substitute for the primary metal. Another factor is the possible changes in the regulations to encourage the use of scrap metals and to make transportation costs for scrap metals equitable. These factors taken together make projections of the supply of secondary nonferrous metals a difficult task.

2.2 Location

There are probably between 400 and 600 establishments that produce secondary nonferrous metals. These are located near population centers where scrap metal is generated. Information on the location of the establishments is available from various sources but is not very reliable. Almost no information is available on output, process, or control equipment.

Total production in this industry can be allocated to the various regions on some sort of shift and share basis. The population of each region, the potential supply of scrap metal, and the access to markets for this metal are all important considerations. Because the industry comprises many small establishments, the new plant problem is a very severe one. The best approach is probably to project output on a regional basis rather than on an establishment basis. If an area does not presently have an establishment and it appears likely that it might in the future, then the model can be run under this assumption.

3.0 SUMMARY

The major task in projecting emissions from the secondary nonferrous metals industry is to project the domestic supply of the output. The location of production can be done using rather crude shift and share analysis. Little data are available on production by region and because the emissions from any one source are so small detailed analysis is difficult and probably not warranted.

APPENDIX I

THE PULP AND PAPER INDUSTRY

1.0 INTRODUCTION

The pulp and paper industry is an important source of particulate emissions. Pulp mills, the primary polluter, may be found in one of at least three different SIC classifications. Detailed information is not available on the production processes at all pulp mills. Not as much data are available on sulfite process mills as on sulfate process mills because they have not been examined in previous studies of air pollution. Nevertheless, they are substantial sources of emissions. A complicating factor in projecting emissions from the paper and pulp industry is the influence of recycled paper. It appears likely that much larger percentages of paper will be recycled in the future.

2.0 PROJECTION CHARACTERISTICS

2.1 Demand and Supply

2.1.1 Demand

The demand for paper products can be forecast readily on the basis of growth in population and GNP. The demand for pulp, of course, is dependent upon the demand for paper. The only factor that requires special treatment are exports, which are fairly substantial in the area of Kraft paper.

2.1.2 Supply

The supply of pulp and paper, in general, will be equal to the demand for it, as there are very small imports. There are some imports across the Canadian border, but these are very small and can be included in the projection methodology. The primary problem of supply is to project the amount of paper that will be recycled. The percentage has been declining over time, but it appears likely that the trend will be reversed due to various economic and social pressures. Recycled paper production does not cause the same emissions as virgin paper production.

2.2 Location

The location of pulp and paper mills depends upon the availability of water, land, and trees. Transportation and access to market are also important considerations. Existing plants will probably produce much of the future supply of paper pulp, but new mills undoubtedly will be established. It should be possible to select broad regions where paper mills will be established, but selecting the particular county in the region may be difficult.

The allocation of production among existing plants can be based on their capacities and trends in production. The investment cycle in the pulp and paper industry is such that there are often large amounts of excess capacity. Therefore, it is likely that the plants with excess capacity can absorb the demands for increased production in the future. The various relevant location factors will have to be studied in order to allocate production among plants and to estimate where new plants will be located.

2.3 Process

Both the sulfate and sulfite processes create emissions; the emissions from the sulfate process are more significant. The mechanical process does not generate much in the way of emissions. Data are not available on all the details of production process at each mill and will have to be obtained.

Additional problems in projecting emissions arise from the presence or absence of lime plants at or near paper mills. Although these lime plants will be considered under the lime industry, their location may be determined during the study of the paper industry. A further problem is that some paper mills generate their own power and emissions from this activity must be considered.

3.0 SUMMARY

There are several substantial tasks to be accomplished in projecting emissions from the paper and pulp industry. Data will have to be obtained on production process at each mill, particularly for mills that employ the sulfate process. In addition, total supply of pulp and paper will require in-depth study in order to determine the influence of recycling larger percentages of paper. Production can be allocated among existing plants with various techniques, but new plants also have to be considered. Their locations can be predicted down to relatively small regions of perhaps fifteen counties, but the exact location within the region is impossible to predict with any degree of confidence. The projection model can be operated with different combinations of likely locations.

APPENDIX J

PHOSPHATE FERTILIZER INDUSTRY

1.0 INTRODUCTION

The phosphate fertilizer industry, found in SIC 2871 and SIC 2819, is a substantial emitter of particulate and fluoride pollution. Most of the particles are emitted from grinding, crushing, and drying of the phosphate rock, which can be handled separately. The phosphate fertilizer industry is a source only of fluorides, which is not a set one or set two pollutant and thus the industry could be dropped from consideration as a point source.

2.0 PROJECTION CHARACTERISTICS

2.1 Demand and Supply

2.1.1 Demand

The demand for phosphate fertilizer is dependent upon the output of agricultural products. Trends in the relationship between phosphate fertilizer and agricultural output can be projected into the future. The demand should be expressed in terms of P_2O_5 equivalent which is the actual nutrient. Fertilizer composition has been changing over time towards a more concentrated form in order to reduce the shipping charges.

2.1.2 Supply

Almost all phosphate fertilizer is produced from domestic sources. In fact there is some small amount of exports that have to be included. Supply can be projected once demand is known. The only consideration might be the particular form that the fertilizer, i.e. normal superphosphate, triple superphosphate or ammonium superphosphate.

2.2 Location

Total supply has to be distributed on a regional basis. The basic phosphate fertilizer production is found near sources of phosphate rock in Florida and Texas. Production of mixed fertilizers is concentrated near agricultural areas in different parts of the country. Growth and output can be allocated among existing plants on a shift and share basis. The most likely locations for new establishments can be predicted.

2.3 Process

The amount of fluorides emitted varies with the type of process used. If emissions in the phosphate fertilizer industry are to be projected, additional data will be required on the production process used at each establishment.

3.0 SUMMARY

The phosphate fertilizer industry is a source only of fluorides, if phosphate rock dust a source of particulates is omitted from consideration. Additional data will be necessary on production process as emissions vary substantially depending on the process. The demand for and supply of phosphate fertilizer probably can be calculated quite readily on the basis of projections of agricultural output. The allocation of output from existing establishments can be done rather easily once the production process used at each establishment is known.

APPENDIX K

SULFURIC ACID

1.0 INTRODUCTION

The sulfuric acid industry, SIC 28193, is an emitter of particles and sulfur oxides. Control practices within the industry are changing and these changes will accelerate in the future. Sulfur recovered through control can be used in the acid making process. There are several surveys in progress on sulfuric acid markets, though nothing definitive has been completed yet. The major task will be to clarify the supply and demand situation, particularly the supply situation. Once this has been done allocation on a regional basis will follow almost automatically.

2.0 PROJECTION CHARACTERISTICS

2.1 Demand and Supply

2.1.1 Demand

Sulfuric acid has been an important low priced inorganic acid used in many industrial processes. The demand derives from the level of industrial activity. On the basis of past trends and knowledge of the various uses for sulfuric acid, projections of demand can probably be made quite easily. It is likely that the price elasticity of demand for sulfuric acid is quite low.

2.1.2 Supply

The supply situation in the sulfuric acid market is chaotic at the present time. Emission controls have resulted in large amounts of sulfur being recovered from emissions from combustion, smelting, refining, etc. This sulfur can easily be convered to sulfuric acid and in fact, much of the sulfur is removed in the form of sulfuric acid. The sulfur potentially available from copper smelters would be more than sufficient to overwhelm the sulfuric acid market in the West. Sulfur from refineries could flood the gulf coast market for sulfuric acid. East coast markets probably could be served with the by-product sulfur from refineries and electric power generation plants.

In any case, the supply of sulfuric acid will be more than adequate to meet the demand for it. But whether it will be produced from present sulfuric acid plants or as a by-product is not currently known. Sulfuric acid production as a by-product would not produce substantial emissions. If by-product sulfuric acid is the primary source of supply, the industry can probably be eliminated as a point source of pollution.

2.2 Location

The supply problem with respect to sulfuric acid is directly related to location. If by-product sulfuric acid supplies the market, the location of sulfuric acid production will be substantially different from what it is today. If, for some reason, by-product sulfuric acid is more expensive or in the wrong location to be competitive with primary sulfuric acid, production can be allocated among existing plants on a regional basis through shift and share analysis. There is almost complete plant data available though it can be improved. Production process information will not be required because variations within plants are greater than the variation among plants.

3.0 SUMMARY

The major task in projecting emissions from sulfuric acid will be to determine how it will be supplied in the future. If it will be supplied through by-products, then a detailed study will be necessary to determine which sources of sulfuric acid will be used. Given the uncertainty at the present time, projection of this industry will be time consuming and not very conclusive. Perhaps the best course of action may be to simply project current output at a steady rate until other studies underway are completed.

APPENDIX L

RUBBER TIRES

1.0 INTRODUCTION

The rubber tire and inner tube industry, SIC 3011, is a minor emitter of particles. The major emission is carbon black, a valuable material that the manufacturers try to capture. The newer plants are successful in eliminating virtually all emissions and the older ones are already controlling emissions at a high level.

2.0 PROJECTION CHARACTERISTICS

2.1 Demand and Supply

2.1.1 Demand

The demand for rubber tires is a function of the number of vehicles in use, the type of tires used and the number of miles traveled per vehicle. The latter factor has not changed very much over time. There have been increases in the mileage per tire due to improvements in the tire body and the tread rubber.

2.1.2 Supply

The supply of tires from domestic sources may be more difficult to project than the demand because of the influence of imports. Imported tires have been increasing as a percentage of total supply, although the percentage is still very small. Furthermore, as imports of a particular type tire increase, there is a tendency to establish production facilities in the U.S.

2.2 Location

Tire production is still concentrated in Ohio due to the historical accident of the first rubber production occurring there. New plants have been established in other areas of the country, particularly in the South where wage rates and other economic conditions are favorable to the efficient production of tires. In general, the new plants that have been established and that will be established do not produce emissions or pollutants. Therefore the only task will be to determine what portion of output will be produced in existing plants. This can probably be done on the basis of projecting current trends.

3.0 SUMMARY

There is some question whether rubber tire production should be considered as a point source of air emissions because of the small quantity of emissions and declining trends in these emissions. If it is projected as a point source, there are two tasks that can be accomplished very easily. One is to project the demand for rubber tires. Consideration will have to be given to the type of tire in use and to the percentage of imports. The other task is to allocate output among existing plants, particularly among the older plants that are more likely to emit pollutants.

APPENDIX M

COAL CLEANING

1.0 INTRODUCTION

Coal cleaning is an important source of particles that are emitted during the drying process. About 65 percent of all coal is cleaned and this percentage has been increasing. It will be necessary to determine where the coal cleaning plants are located, their production levels, and the process used.

2.0 PROJECTION CHARACTERISTICS

2.1 Demand and Supply

2.1.1 Demand

Coal cleaning is a process for removing dirt, clay, rock, shale, sulfur compounds and other materials from raw mine-run coal. Cleaning can improve the quality of the coal by increasing the BTU value, by reducing the ash content, and by reducing the shipping costs. Coal cleaning has been increasing over time due to the increasing costs of transportation. At present about 65 percent of all coal is cleaned. This percentage is likely to increase, at a rapid rate, if coal cleaning proves effective in reducing the sulfur content of the coal. However, current opinion is that coal cleaning is not very effective in reducing the sulfur content and so the trend toward coal cleaning will probably continue at about the same rate.

The demand for coal cleaning is dependent upon the total demand for coal and the price of transportation relative to the price of coal. Ash disposal problems also influence this demand. Examination and extrapolation of present trends probably will be adequate to project the percentage and quantities of coal that will be cleaned in the future.

2.1.2 Supply

The supply and demand for coal cleaning has to be considered as a single problem. The demand for cleaning depends upon the cost at which coal can be cleaned and the cost of transportation. In general, coal cleaning will be demanded so long as the coal can be cleaned at a lower cost than the cost of transporting, and later disposing of, dirt and other undesirable materials that are mixed with the coal. The percentage of coal that is exported may also affect the percentage that is cleaned.

2.2 Location

The primary task in projecting emissions from this industry will be to determine the location, production level and process used at present coal cleaning plants. The Bureau of Mines presents aggregated data, but does not break it down on a regional basis. Once present and past data have been collected, it should be possible to project the regional distribution of future output on the basis of shift and share analysis. Detailed information may be required on the production rates of coal at the various coal cleaning plants to determine whether the present trends of regional output will be maintained.

The most likely location of new coal cleaning plants will have to be identified. The projection model can be run using these most likely locations in order to see the effects on regional emissions of air pollution.

2.3 Process

Emissions from the cleaning operation depend upon the type of process used. The two methods are the wet wash and the dry wash. In the wet wash, the coal subsequently is dried by either flash dryers or fluidized bed dryers. Emissions vary with the type of dryers as well as the type of wash. The process types in operation at existing facilities are not known. Substantial effort will have to be devoted to obtaining these data.

3.0 SUMMARY

The major task in projecting emissions from the coal cleaning industry will be to obtain data on the present location, production level, and processes used by existing coal cleaning plants. A secondary task will be to project the percentage or quantities of coal that will be cleaned in the future. Once these two tasks are accomplished, the projected output can be allocated to existing plants on the basis of capacity at these plants, trends in production, and other considerations. Likely locations for new plants can be hypothesized.

APPENDIX N

FEED AND GRAIN INDUSTRY

1.0 INTRODUCTION

The feed and grain industry is a major source of particulate emissions. The type and quantity of emissions is a function of the elevator type and the particular grain being handled. There are few data available on country elevators and small, part-time feed mills. The main problem, however, is with the terminal elevators and the large feed producers for which information is available.

2.0 PROJECTION CHARACTERISTICS

2.1 Demand and Supply

2.1.1 Demand

The demand for output from the feed and grain industry is a function of agricultural output. All grain production moves through grain elevators regardless of immediate demand for the product. The grain may be stored for export or future domestic uses. Feed production on the other hand, is directly related to the immediate demand for animal products, most of which is consumed within the United States.

The demand for grain storage and processing can probably best be related to projections of agricultural output made by the Federal government. Similarly, these projections can also be related to the projected demand for animal products.

2.1.1 Supply

The supply of output from the grain and feed industry is essentially equal to the demand for their services. Because of data requirements, the most reasonable approach may be to handle country elevators, and terminal elevators and large feed mills separately. The country elevators and small feed mills are located around the country, very little infomration is known about them, and they operate on an intermittent basis. The terminal elevators and large feed mills operate on a much more continuous basis, data are available on them, and they are likely to be more significant sources of emissions because of their size and location in populated areas.

2.2 Location

Country elevators are spread evenly across grain producing areas. Terminal elevators on the other hand, are located at major shipping points and near large markets. This pattern and, in fact, specific locations should not change. The locational problem therefore, will be to allocate projected output among existing sources. This can be done on the basis of present trends and projections of regional output made by the Department of Agriculture.

3.0 SUMMARY

Projecting emissions from all country elevators and small feed mills would be a difficult and probably unsatisfactory task. The country elevators operate on an intermittent basis and only affect the area directly around them. Because data are not already available, effort to project this group of sources is probably not worthwhile. Efforts should be concentrated on projecting output for the terminal elevators and the large feed mills. Total output can probably be based on projections made by the Department of Agriculture. This output then has to be allocated among various existing establishments. The degree of control at these various establishments will have to be determined in order to project emissions.

APPENDIX O

ASPHALT BATCHING

1.0 INTRODUCTION

The asphalt batching industry consists of a large number of establishments producing liquid asphalt and tar paving materials. These plants are an important source of particulate emission. The biggest problem in projecting emissions is the lack of detailed data about plant locations, production levels, and emission controls in use.

2.0 PROJECTION CHARACTERISTICS

2.1 Demand and Supply

2.1.1 Demand

The demand for asphalt batching is based on the construction of roads, the paving of parking lots and driveways, and the maintenance of roads and other paved areas. Although total road construction and maintenance can probably be projected with a fair degree of confidence, there is uncertainty about the location and whether the paving will be done with cement or asphalt. There have been some shortages of asphalt, which is a residual of oil refining, because of the increased demand for more volatile forms of petroleum. This shortage may eventually permit cement to capture a larger share of the paving market.

2.1.2 Supply

The supply of asphalt batching will generally be equal to the demand except where supplies of the basic material are scarce due to increased demand for other petroleum refinery products. There are more than 1,000 batching plants located in all parts of the country. Whether large or small, the plants are generally located to serve their immediate area. However, there are in addition, many mobile plants that move around to wherever large construction jobs are underway.

2.2 Location

The data problems on the location and production levels of asphalt plants have already been mentioned. When total output has been projected the output can be allocated on a regional basis through the use of shift and share analysis of the data that are available. If the data are not available, allocation of the output on the basis of population and economic activity may be preferable as an alternative to collecting new data.

3.0 SUMMARY

The asphalt batching industry is a substantial emitter of particles and is located in all parts of the country. There is a lack of data on the industry and therefore projections on a regional basis are difficult at best. A practical solution to projecting these emissions may be to allocate them on the basis of population and economic activity. If this course of action is chosen, the critical task will be to estimate total output in the industry on the basis of demand for asphalt paving and quantity that can be supplied. Asphalt may be replaced by cement for some uses because of future shortages.

APPENDIX P

CEMENT

1.0 INTRODUCTION

The cement industry is a very substantial source of particulate emissions and is found in all parts of the United States. The industry is localized because of the low value to bulk ratio, but there are changes underway in distribution patterns. Forecasting the distribution patterns will be the most difficult part of this project. Present location of plants, levels of production, trends in output, production process and controls are all available.

2.0 PROJECTION CHARACTERISTICS

2.1 Demand and Supply

2.1.1 Demand

The demand for cement is a function of construction activity. It is likely that available projections of construction activity on a national and regional basis can be used as a means of projecting the output of cement. It may be necessary to modify these projections in order to take into account changes in the relative positions of asphalt and cement for paving purposes. There are some exports of cement and a prediction of these exports is necessary.

2.1.2 Supply

Most of the demand for cement is met by domestic production. There is some small amount of cement coming from Canada and this has to be taken into consideration. In general, however, projecting the supply of cement is not a problem.

2.2 Location

The allocation of production among regions is the most important part of projecting emissions from the cement industry. Detailed information is available on existing plants and can be used to allocate output among regions. However, there is a tendency to close some plants and shift production to a more advantageous location. Bulk shipments are now made to a larger market than was true in the past. It will be necessary to project such trends toward a terminal distribution pattern. Information on existing plants should provide guidance in predicting the plants that are likely to close in the future. Locational analysis can then be used to estimate where new plants will be located in order to minimize transportation costs. In general, the new plants do control emissions to the level required by the standards, though there are some emissions that escape.

3.0 SUMMARY

The major task in projecting emissions from the cement industry will be to allocate output on a regional basis. In particular, it will be necessary to estimate new locations for large distribution terminals. The secondary problem will be to determine the demand for and supply of cement. In general, the demand element will be more difficult to project.

APPENDIX Q

BRICK MANUFACTURING

1.0 INTRODUCTION

Brick making is a potential source of fluoride emissions if the raw material has a high fluoride content. If fluorides are not considered in this model, then the brick making industry will drop out.

2.0 PROJECTION CHARACTERISTICS

2.1 Demand and Supply

2.1.1 Demand

The demand for bricks has been growing slowly because the cost of installed brick is higher than the installed cost of other materials. This is due to rapidly rising labor costs. This trend is likely to continue unless there is some substantial change in technology or institutional arrangements. For example, brick layers may lay more bricks per hour if union rules are changed, or if pre-cast brick panels come into common use. Neither of these events is likely to occur in the near future, however.

Demand can be projected by making brick manufacturing a function of construction activity. This function can be projected and then applied to the absolute amount of construction activity projected.

2.1.2 Supply

The supply of brick is usually equal to demand because there are no imports or exports.

2.2 Location

The distribution of brick plants in the United States is determined by the population distribution, the availability of simple clay for brick making, and local cost for competitive building materials. The location of output can probably best be projected by the use of shift and share analysis based on current trends. It will be necessary to determine which plants use clay with a high fluoride content.

3.0 SUMMARY

Brick making is a source of fluoride emissions and will be dropped from this model if fluoride emissions are not included. If they are included, the projection of emissions will require three relatively minor tasks. The first will be to determine the national output in the industry based on the percentage of building materials captured by the brick industry. The second task will be to allocate this output on a regional basis through the use of shift and share analysis. The third task will be to determine those establishments that use clay with a high fluoride content.

APPENDIX R

LIME INDUSTRY

1.0 INTRODUCTION

The lime industry is a very substantial emitter of particles. Lime plants are found not only as independent plants but also as subsidiaries that may be adjacent to or removed from pulp and paper mills and steel mills. The location of all lime plants is not known with certainty nor are details on plant operations. The most difficult task in projecting emissions from the lime industry will be to obtain data on production and process types by plant. The secondary task will be to project total output and to allocate this on a regional basis.

2.0 PROJECTION CHARACTERISTICS

2.1 Demand and Supply

2.1.1 Demand

The demand for lime is growing rapidly because of the growing use of basic oxygen furnaces in the steel industry. This process requires more lime than the open hearth furnaces. Rapid growth in the paper and pulp industry, and new uses for lime such as soil stabilization, water treatment, and sewage treatment also create increasing demand. Projections of lime production will depend upon the growth of the steel and pulp industry as well as the success of lime in capturing new markets. The national demand for lime will be projected as a function of the various uses to which it is put.

2.1.2 Supply

The quantity of lime supplied will be about equal to the demand because imports are not an important consideration. There may be some lime recycled from its use in pollution control equipment. This is a minor consideration, however. The regional distribution of lime production will be a more difficult task.

2.2 Location

The most difficult aspect of projecting the location of lime plants is the extreme shortage of available data on plant location, production and processes. One possible reason for this lack of data is the large number of captive lime plants that belong to steel or paper mills. It is likely that a direct survey of lime plants will be required in order to acquire the necessary data.

Even with data on the current location of lime production, projections of location of this industry will require intensive study. The number of plants has been declining due to economies of scale. While there is some evidence that the number of plants has stabilized recently, there may still be additional closures. The most likely possibility for the next ten years will be an expansion of output at existing plants. The task, therefore, is to project the share of national market for each of these establishments. The plants that enjoy a locational advantage relative to markets will probably be the ones that increase their share. A location study employing various economic variables should be done in order to allocate shares to each of the regions. If this analysis is not successful in explaning the location of present production, than a simple shift and share analysis may give better results for projection purposes.

2.3 Process

Data will be necessary on the type of process used at each lime establishment. Emission factors vary substantially between vertical kilns and rotary kilns. Although rotary kilns have been increasing in popularity during the last ten years or so, there is some evidence that vertical kilns may stage a comeback because of the lower emission control cost.

Data will also have to be collected on the type of fuel used at lime kilns because the emissions vary with the type of fuel.

3.0 SUMMARY

The major task in projecting emissions from the lime industry will be to collect data on an establishment basis for production levels, type of kilns and the fuel used. Trends in production over time will be particularly useful for projecting the share of the national market that will be held by each establishment. Although projecting national demand will require some effort, the much larger effort will have to be devoted to the regional distribution of production.

APPENDIX S

GASOLINE MARKETING AND BULK STORAGE

1.0 INTRODUCTION

The gasoline marketing and bulk storage industry, SIC 5092, is a substantial source of hydrocarbons. The hydrocarbons evaporate from the storage tanks and also escape during the filling process. These emissions are effectively controlled through the use of floating roof tanks and submerged fill lines. Many of the existing tanks have these devices because they prevent the loss of a valuable product. It is likely that this industry will decline over time as a source of emissions.

2.0 PROJECTION CHARACTERISTICS

2.1 Demand and Supply

2.1.1 Demand

The demand for the services of the industry, which may be measured in terms of throughput of gasoline, depends upon gasoline consumption in the surrounding market area. This gasoline consumption can probably be taken from the study of mobile sources. It is likely that the throughput at the larger terminals is proportionally greater than gasoline consumption because these terminals also distribute gasoline to smaller storage establishments. In general, the projection of demand on a national basis and on a regional basis should not require great effort.

2.1.2 Supply

The quantity of throughput in each area will be equal to the demand for the gasoline. There is not very much information available on the total number of storage tanks or on the type of tanks in use. Even less data are available on the size of tanks and the controls in use by location.

2.2 Location

Distributing output in this industry to each region can be done in two different methods. The first is to gather detailed data on tank size and the controls for each establishment. There are more than 29,000 establishments in the United States in 1967 and the data gathering required would be extensive. An alternative and a much cheaper method consists of assuming how many tanks are required in an area to handle the throughput expected on the basis of population and gasoline consumption. A number of assumptions can be made on the type of tanks and the expected emissions from each area. As mentioned above some areas will have storage facilities much larger than expected on the basis of their population. These large terminals can be identified in particular AQCR's and probably can be projected.

3.0 SUMMARY

Lack of data about the gasoline marketing and bulk storage industry is the greatest obstacle to projecting emissions on a regional basis. It is possible to project emissions using a number of assumption about throughput and about the type of tanks and controls devices in use. If desired, factual data can be supplied for the bulk terminals and then used as a basis for making projections in these AQCR's. EPA might also consider dropping this industry because of the relatively low emissions from each source and the declining rate of emissions.